GTE-ERS
TECHNICAL LIBRARY
12812

Instruction Manual

No. EB 2300B

for

FM/AM Modulation Meter

TF 2300B

Model No. 52300-920

mi
Technical Publications

©
1974

MP MASTER
MA30927

MARCONI INSTRUMENTS LIMITED
ST. ALBANS HERTFORDSHIRE ENGLAND

G.L. 2.5c
7/75/D

EB 2300B
1c - 7/75

Contents

Chapter 1 GENERAL INFORMATION

1.1 Introduction ... 5
1.2 Data summary ... 6
1.3 Accessories ... 9

Chapter 2 OPERATION

2.1 Installation ... 12
2.2 Power supply ... 12
2.3 Controls and connectors ... 12
2.4 Preparation for use ... 14
2.5 Measuring f.m. deviation ... 14
2.6 Measuring a.m. depth ... 14
2.7 Measuring f.m. on a.m. ... 15
2.8 Measuring a.m. on f.m. ... 15
2.9 Noise measurements ... 16
2.10 Oscillator arrangements and operating notes ... 18
2.10.1 Internal oscillator ... 18
2.10.2 External oscillator ... 18
2.10.3 Use above 1200 MHz ... 18
2.11 Use of crystal oscillator TK 2302 ... 18
2.11.1 Fitting the crystal oscillator ... 18
2.11.2 Crystal selection ... 19
2.11.3 Crystal oscillator operation ... 20
2.12 Measurement in 1 to 2 MHz range ... 20
2.13 Asymmetric modulation and carrier shift ... 20
2.14 Use of l.f. output socket ... 20
2.15 Use of i.f. output socket ... 20
2.16 FM stereo measurements ... 21
2.16.1 Harmonic distortion ... 21
2.16.2 Channel separation ... 22
2.17 Phase modulation ... 23
2.18 Telemetry deviation ... 23

Decibel conversion table ... 24

Chapter 3 TECHNICAL DESCRIPTION

3.1 Introduction ... 26
3.2 Circuit summary ... 26
3.3 Mixer - unit A1 ... 27
3.4 Local oscillator - units A2, A2a and A2b ... 27
3.5 IF amplifier - unit A3 ... 28
3.6 Limiter - unit A4 ... 28
3.7 Discriminator - unit A5 ... 28
3.8 200 kHz low-pass filter - unit A6 ... 29
3.9 1st l.f. amplifier - unit A7 ... 29
3.10 15 kHz low-pass filter - unit A8 ... 29
3.11 2nd l.f. amplifier - unit A9 ... 29

3.12 Peak reading voltmeter - unit A10 30
3.13 AM detector - unit A11 30
3.14 Calibrator - unit A12 30
3.15 Power supply - unit A13 30
3.16 Crystal oscillator - TK 2302 31

Chapter 4 MAINTENANCE

4.1 Introduction 33
4.2 Access and layout 33
4.3 Performance checks 33
4.3.1 Test equipment required 33
4.3.2 RF input and i.f. output 33
4.3.3 FM deviation accuracy 37
4.3.4 AM depth accuracy 38
4.3.5 FM noise 39
4.3.6 FM distortion 39
4.3.7 AM rejection 40
4.4 Cleaning and lubricating 41

Chapter 5 REPAIR

5.1 Introduction 42
5.2 Fault location 42
5.2.1 Test equipment required 42
5.2.2 Front panel checks 42
5.2.3 Internal checks 43
5.3 Waveforms 43
5.4 Realignment 43
5.4.1 Introduction 43
5.4.2 Test equipment required 43
5.4.3 Power supply (A13) 43
5.4.4 Local oscillator (A2, A2a and A2b) 45
5.4.5 Minimum sensitivity 47
5.4.6 De-emphasis 48
5.4.7 Range attenuator 48
5.4.8 AM and i.f. response 49
5.4.9 Discriminator trigger 49
5.4.10 Set i.f. 49
5.4.11 LF and discriminator noise 49
5.5 Replacement of sub-assemblies 50
5.6 Oscillator drive cord 51
5.7 Replacement of components 51

Chapter 6 REPLACEABLE PARTS

Introduction and ordering 52

Chapter 7 CIRCUIT DIAGRAMS

Circuit notes 64
Fig. 7.1 Inter-unit wiring 65
Fig. 7.2 Mixer, oscillators and i.f. amplifier 67
Fig. 7.3 Limiter, discriminator and 1st l.f. amplifier 69
Fig. 7.4 2nd l.f. amplifier and peak reading voltmeter 71
Fig. 7.5 AM detector and calibrator 73
Fig. 7.6 Power supply unit 75

Chapter 1

General information

1.1 INTRODUCTION

The TF 2300B Modulation Meter measures f.m. deviation and a.m. depth. With its wide range of deviation frequency, modulation bandwidth and carrier frequency, the instrument is suitable for application to fixed and mobile point-to-point communications, broadcasting, telemetry and multi-channel link equipment in the h.f., v.h.f. and u.h.f. bands. Distortion and channel separation tests on f.m. stereo transmitters can also be made.

Positive and negative f.m. deviation can be measured in ranges from 1.5 kHz to 500 kHz full-scale at modulation frequencies between 30 Hz and 3.4 kHz on the 1.5 kHz deviation range, and 30 Hz and 200 kHz on all other deviation ranges. AM depth can be measured up to 95% in a 30 Hz to 50 kHz modulation bandwidth. Either f.m. or a.m. can be measured in the presence of the other. Although measurements are normally made by means of the meter readout, i.f. and demodulated outputs are available at the front panel for examination or analysis.

Spurious a.m. and f.m. due to hum and noise are kept to a level insignificant for most applications but, where required, an optional crystal oscillator can be fitted, or an external local oscillator may be used. The instrument can be operated without a local oscillator for measurements in the 1 to 2 MHz range.

Fig. 1.1 FM/AM Modulation Meter TF 2300B with Crystal Oscillator TK 2302

1.2 DATA SUMMARY

FM measurement

Carrier frequency range :	4 to 1200 MHz.
Deviation range :	Six ranges with full-scale indications of 1.5, 5, 15, 50, 150 and 500 kHz. Positive or negative deviation indication selected by a switch.
Modulation frequency :	30 Hz to 200 kHz on all ranges except the 1.5 kHz deviation range which is limited to 30 Hz to 3.4 kHz.
Accuracy :	±3% of f.s.d. for deviations up to ±500 kHz and modulating frequencies between 30 Hz and 150 kHz. ±5% of f.s.d. on the 1.5 kHz deviation range. ±10% of f.s.d. for deviations up to 500 kHz and for modulating frequencies between 150 kHz and 200 kHz.
AM rejection :	Additional deviation error typically less than 150 Hz in a 15 kHz bandwidth when the a.m. depth is 80% and the modulating frequency is 1 kHz.
Inherent noise :	Deviation less than -50 dB relative to a level of 5.0 kHz deviation in a -3 dB bandwidth of 50 Hz to 15 kHz from 4 to 200 MHz (typically -56 dB); less than -40 dB from 200 to 1038 MHz (typically -46 dB).

AM measurement

Carrier frequency range :	4 to 400 MHz.
Modulation depth range :	Two ranges with full-scale indications of 30% and 100%. Peak and trough indications selected by a switch.
Accuracy :	±3% of f.s.d. for modulating frequencies between 30 Hz and 15 kHz, and modulation depths up to 80%. ±5% of f.s.d. for modulating frequencies between 30 Hz and 50 kHz, and modulation depths up to 95%.

RF input

Frequency range :	4 MHz to 1200 MHz in 11 bands as follows : 4 to 8, 8 to 15, 15 to 27, 27 to 48, 48 to 84, 84 to 147, 147 to 255, 255 to 426, 426 to 650, 650 to 1038 and 1038 to 1200 MHz. Usable with reduced sensitivity up to 1600 MHz with internal oscillator and at higher frequencies with an external oscillator.
Calibration accuracy :	±3%.
Sensitivity :	Less than 12 mV between 4 and 426 MHz (typically 5 mV). Less than 35 mV between 426 and 1038 MHz (typically 15 mV). Less than 100 mV between 1038 and 1200 MHz (typically 50 mV).
Maximum input :	3 V r.m.s. (200 mW).
Input impedance :	Nominally 50 Ω.

IF output

Frequency :	Nominally 1.5 MHz.
Amplitude :	Between at least 220 mV and 1 V e.m.f.
Output impedance :	Nominally 10 kΩ.

LF output

Frequency range :	30 Hz to 200 kHz with switchable 15 kHz low-pass filter on f.m. except on the 1.5 kHz deviation range. 30 Hz to 3.4 kHz on the 1.5 kHz deviation range. 30 Hz to 50 kHz on a.m. (Typical response curves are shown in Fig. 1.2.)
Noise filter :	Modifies response to a nominal -3 dB bandwidth of 50 Hz to 15 kHz for noise measurements at output terminals only. Usable for f.m. and a.m.
Stereo :	Channel separation typically 44 dB from 200 Hz to 15 kHz decreasing to 39 dB at 50 Hz. Suitable for measurements on stereo transmitters designed to meet FCC regulations and CCIR Report 293-2.
De-emphasis :	Switchable to 0, 50, 75 or 750 μs.
Output level :	Nominally 0 dBm into 600 Ω when meter reads full-scale, except on the 1.5 kHz deviation range when the output is nominally -10 dBm.
Distortion, f.m. :	Less than 0.2% for f.m. deviations up to ±75 kHz and modulating frequencies up to 15 kHz. (Typically 0.1%.) Less than 0.3% for f.m. deviations up to ±300 kHz and modulating frequencies up to 25 kHz. (Typically 0.2%.) Less than 3% for f.m. deviations up to ±500 kHz and modulating frequencies up to 200 kHz. (Typically 2%.)
Distortion, a.m. :	Less than 1% for a.m. depths up to 80%. (Typically 0.5% up to 60% depth.) Less than 2% for a.m. depths between 80% and 90%. (Typically 1.0% between 60% and 90% depth.)

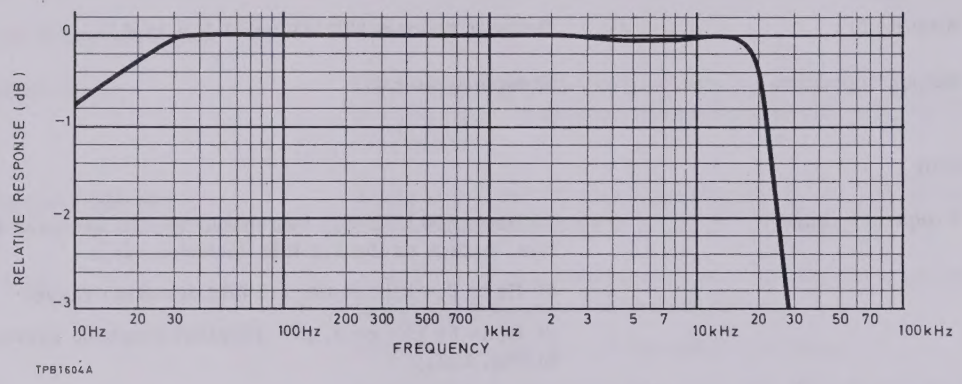
Power requirements

AC mains :	95 V to 130 V or 190 V to 260 V, 45 to 500 Hz.

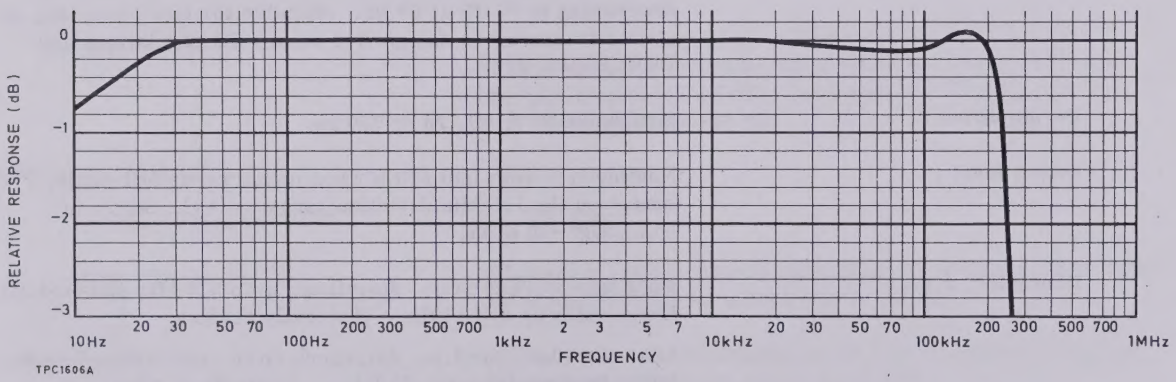
Dimensions and weight

Height	*Width*	*Depth*	*Weight*
175 mm (7 in)	426 mm (16 3/4 in)	380 mm (15 in)	12.5 kg (27.5 lb)

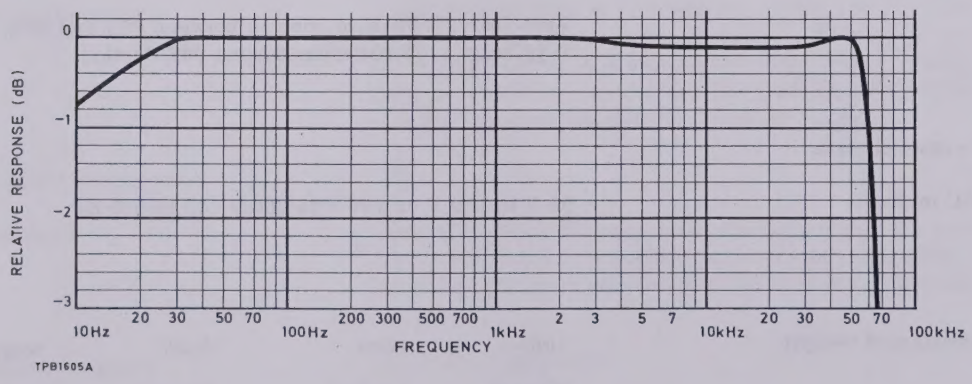
Fig. 1.2 Typical demodulated frequency response curves for meter and l.f. output with de-emphasis off



(a) FM, 15 kHz filter



(b) FM, 200 kHz filter



(c) AM, 50 kHz filter

1.3 ACCESSORIES

Supplied

44688-003 EXTENSION BOARD, TM 7926

For use when servicing printed circuit boards.

43129-003 MAINS LEAD, TM 7052.

Optional

52302-900 CRYSTAL OSCILLATOR, TK 2302

Provides an alternative to the internal variable local oscillator, particularly for low noise measurements at high frequencies. Fits into the recess in the front panel.

Frequency range :	80 to 1000 MHz for f.m., 80 to 400 MHz for a.m.
Sensitivity :	Less than 12 mV between 80 and 500 MHz (typically 5 mV). Less than 100 mV between 500 and 1000 MHz (typically 30 mV).
FM noise :	Deviation relative to a level of 5 kHz deviation in a 3 dB bandwidth of 50 Hz to 15 kHz is less than : -52 dB up to 800 MHz (typically -56 dB), -50 dB from 800 to 1000 MHz (typically -55 dB).
Crystals :	Up to three switch selected crystals may be used. Marconi type QO 1670 series, in fundamental frequency range 40 to 60 MHz.

54452-011 SIGNAL SNIFFER

T connector for insertion between transmitter and load with pick-up to give a small signal from the T branch to the modulation meter.

Attenuation :	Dependent upon frequency. Approximate range is -66 dB at 4 MHz reducing to -17 dB at 1200 MHz when terminated by 50 Ω.
Dimensions :	66 mm x 66 mm x 15 mm (2.6 in x 2.6 in x 0.6 in).

54431-021 20 W, 50 Ω, 20 dB ATTENUATOR

Attenuator for use with signal sniffer where additional attenuation and/or termination is required with transmitters up to 30 W.

Attenuation :	20 dB nominal.
Frequency range :	DC to 1 GHz.
Impedance :	50 Ω nominal.
Rating :	20 W continuous. 30 W for up to 5 minutes with off periods of at least 5 minutes.
Connectors :	50 Ω, BNC plug to BNC socket.
Dimensions :	66.4 mm long x 38 mm dia. nominal (2.625 in x 1.5 in nominal).

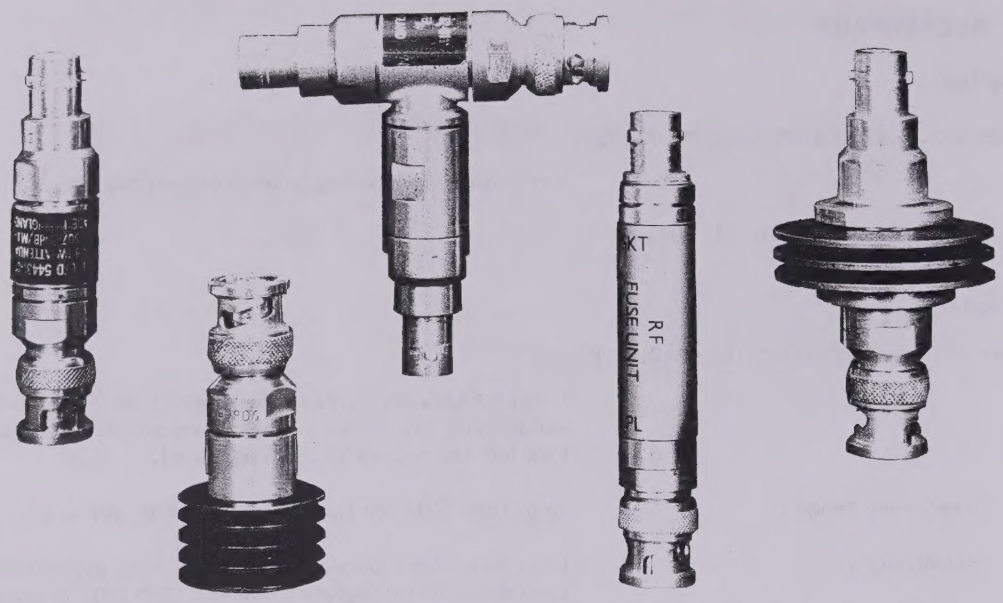


Fig. 1.3 1 W 50 Ω 20 dB Attenuator, 12 W 50 Ω Termination, Signal Sniffer, RF Fuse Unit and 20 W 50 Ω 20 dB Attenuator

54431-011 1 W, 50 Ω, 20 dB ATTENUATOR

Attenuator for use with signal sniffer or where termination is required with transmitters up to 1 W.

Attenuation :	20 dB nominal.
Frequency range :	DC to 1GHz.
Impedance :	50 Ω nominal.
Rating :	1 W continuous.
Connectors :	50 Ω, BNC plug to BNC socket.
Dimensions :	66 mm long x 16.5 mm dia. nominal (2.6 in x 0.65 in nominal).

54422-011 12 W, 50 Ω TERMINATION

Termination for use as a good non-radiating termination for transmitters up to 15 W.

Impedance :	50 Ω nominal.
Frequency range :	DC to 1 GHz.
Rating :	12 W continuous. 15 W for up to 5 minutes, with off periods of at least 5 minutes.
Connector :	50 Ω, BNC plug.
Dimensions :	50 mm x 25 mm nominal (2 in x 1 in nominal).

43281-007 RF FUSE UNIT, 50 Ω, TM 9884

Fuse for protection against accidental overload.

VSWR :	Better than 1.4 :1 up to 500 MHz.
Insertion loss :	Better than 0.75 dB at 300 MHz. Better than 1.25 dB at 500 MHz.
Rating :	0.4 W.
Connectors :	50 Ω, BNC plug to BNC socket.
Dimensions :	88 mm x 14 mm (3.5 in x 0.55 in).

54127-131 RACK MOUNTING CONVERSION KIT

Adapts the instrument for use in a 19 inch rack.

41690-079 PROTECTIVE FRONT PANEL COVER

For protection of the front panel during transit.

43126-012 INPUT LEAD, TM 4969/3

50 Ω, 2.44 m (62 in) long, BNC connectors.

WARNING

54431-021 20 W, 50 Ω 20 dB ATTENUATOR
54422-011 12 W, 50 Ω TERMINATION

Beryllia is used in the internal construction of these accessories. This material when in the form of fine dust or vapour and inhaled into the lungs can cause a respiratory disease. Because of this hazard, you are strongly advised not to open the accessory. If a fault is suspected the accessory must be returned for repair to Marconi Instruments Service Division, or disposed of in such a manner that no health hazard will result.

Chapter 2

Operation

2.1 INSTALLATION

Modulation Meter type TF 2300B is available in two versions : with a case for bench mounting, or with a dust cover for rack mounting. Before inserting into a rack, slides or runners should be fitted to the rack to support the instrument and aid location.

2.2 POWER SUPPLY

The modulation meter may be used with a.c. mains only.

The socket of the lead provided with this instrument fits into the plug on the rear panel. The other end of the lead must be fitted with a plug by the user. The three conductors are provided with identification sleeves for this purpose, as follows :

Colour	*Connection*
Brown	Line
Blue	Neutral
Yellow/Green	Earth

Before plugging in to the mains supply, check that the fuse rating and mains voltage setting are correct. For voltages around 230 V, a 100 mA slow-blow fuse is fitted; for 110 V, this must be changed to 160 mA. To change the mains voltage switch setting, remove the L-shaped lock-plate secured by two screws above the switch, slide the switch button into its other position (as shown on the panel), reverse and replace the lock-plate to hold the button in its new position. No other adjustment is needed.

2.3 CONTROLS AND CONNECTORS

The following outline of control functions is intended for reference purposes. Until you are familiar with the instrument, use the operating procedures detailed in later sections.

(1) TUNING dial. Calibrated in terms of r.f. input frequency, i.e. 1.5 MHz below local oscillator frequency.

(2) FREQUENCY RANGE switch. Selects r.f. input range and appropriate internal local oscillator.

(3) TUNE FREQUENCY controls. (Left : coarse - right : fine). Inoperative when using external local oscillator or crystal oscillator plug-in.

(4) OSCILLATOR switch. Selects internal, external or crystal controlled local oscillator (where fitted).

(5) EXT OSCILLATOR socket. Type BNC. Accepts external local oscillator signal of about 200 mV.

(6) RF IN socket. Type BNC. Accepts signal under test.

(7) RF LEVEL control. Adjusts attenuation of signal input at RF IN socket.

(8) IF OUT socket. Type BNC. Connect to counter for measuring carrier shift or to oscilloscope for viewing unfiltered a.m. envelope. Output is 1.5 MHz at about $\frac{1}{2}$ V.

(9) SET AM level control. Adjust for SET reading on meter when FUNCTION switch is at SET AM.

(10) FUNCTION switch. Selects setting up and measuring conditions on f.m. and a.m. Numbers show normal sequence of settings.

(11) MODULATION RANGE switch. Selects full-scale meter range, six for f.m., two for a.m.

(12) FREQUENCY RESPONSE switch. Selects modulation bandwidth in f.m., a.m. and noise measurements.

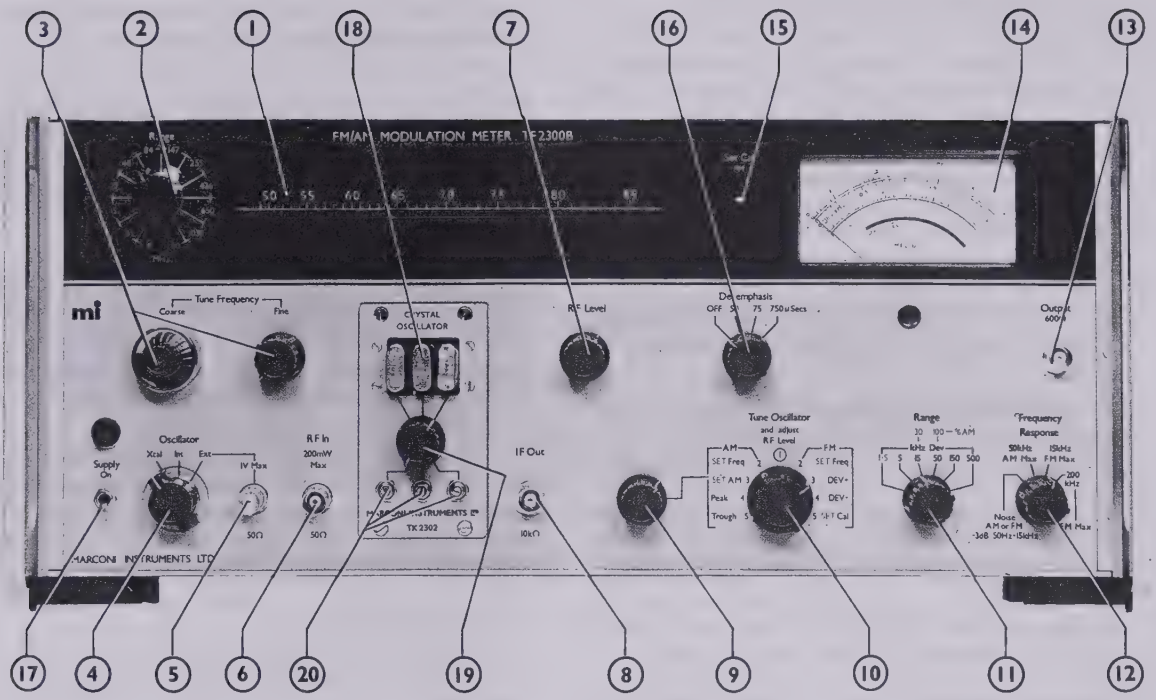


Fig. 2.1 Front panel controls and connectors

(13) OUTPUT socket. Type BNC. Provides demodulated output for connection to extra-sensitive meter, wave analyser etc.

(14) Meter. Reads % a.m. depth and f.m. deviation. RF LEVEL arc applies to position 1 of FUNCTION switch, and SET mark to the four SET positions.

(15) SET CAL FM preset. Standardizes deviation measuring accuracy. Adjust for SET reading on meter with FUNCTION switch at SET CAL.

(16) DE-EMPHASIS switch. Applies de-emphasis to demodulated signal at OUTPUT socket. Does not affect meter readout, except on 1.5 kHz deviation range.

(17) SUPPLY switch. Lamp indicates that supply is on.

Rear panel :

Supply plug. Accepts Mains Lead type TM 7052.

Mains fuse. 100 mA (for 230 V) or 160 mA (for 110 V) slow-blow type.

Mains voltage selector. 230 V position for 190 - 260 V, 110 V position for 90 - 130 V. Reverse locking plate when changing range.

Crystal Oscillator TK 2302 :

(18) CRYSTAL sockets. Accept style D miniature crystals for local oscillator control. See Sect. 2.11 for crystal selection.

(19) CRYSTAL switch. Selects crystal required and corresponding tuning preset.

(20) CRYSTAL tuners. Select correct crystal overtone.

2.4 PREPARATION FOR USE

It is helpful in reading these instructions and in using the instrument until completely familiar with its operation, to remember that where a control or switch position is marked SET, the control should be adjusted to make the meter read on the line marked SET.

Before commencing measurements :

(1) Check the mechanical zero of the meter and adjust, if necessary, by means of the screw.

(2) Turn the RF LEVEL control towards the minimum necessary for the signal level.

(3) Connect the signal to be tested to the RF IN socket at a level which, operating into 50 Ω, will develop a voltage within the limits given in Sect. 1.2 under 'RF input'. At the highest carrier frequencies the shortest possible input lead should be used or an external 50 Ω matching attenuator.

CAUTION. Inputs greater than 3 V r.m.s. may damage the attenuator. If in doubt, use an external attenuator or RF Fuse Unit TM 9884.

(4) Switch on the SUPPLY and check that the red lamp glows.

2.5 MEASURING FM DEVIATION

After carrying out the preparation procedure in Sect. 2.4 :

(1) Set the MODULATION RANGE switch to suit the expected deviation of the signal under test.

(2) Set the FREQUENCY RESPONSE switch to 200 kHz unless the modulating frequency is less than 15 kHz. If so, switch to 15 kHz in order to obtain the best signal-to-noise ratio.

(3) Set the DE-EMPHASIS switch as required. Its setting has no effect on the internal meter reading unless the MODULATION RANGE switch is in the 1.5 kHz deviation position. The de-emphasis is effective on the demodulated signal at the OUTPUT socket.

(4) Set the FREQUENCY RANGE switch to suit the carrier frequency of the signal. For detailed instructions on oscillator arrangements, see Sect. 2.10. In this section, it is assumed that the internal local oscillator will be used.

(5) Set the FUNCTION switch to TUNE OSCILLATOR. Adjust the tuning dial to the carrier frequency. Tune for peak meter deflection, and then adjust the RF LEVEL control for a meter deflection in the black RF LEVEL arc.

(6) Set the FUNCTION switch to FM SET FREQUENCY. Slightly readjust the TUNE FREQUENCY controls until the meter deflects to the SET line. Avoid spurious settings - the correct one is that closest to the original setting obtained in (5).

(7) Set the FUNCTION switch to DEV+ and DEV-. The demodulated peak frequency deviations above and below the carrier frequency may be measured on the meter or viewed on an oscilloscope connected to the OUTPUT socket. Read the meter on the scale corresponding to the setting of the MODULATION RANGE switch.

Note. If unequal readings are obtained, distortion in the equipment under test is indicated. See Sect. 2.13.

(8) Before carrying out a series of measurements, and from time to time during measurements, switch to SET CAL and check that the meter reads SET. If necessary, adjust the f.m. calibration by inserting a screwdriver in the SET CAL FM preset and adjusting until the meter reads SET.

CAUTION. Do not attempt to SET CAL on the 1.5 kHz f.m. deviation range.

2.6 MEASURING AM DEPTH

After carrying out the preparation procedure in Sect. 2.4 :

(1) Set the MODULATION RANGE switch to the 30% or 100% a.m. depth range according to the expected modulation depth of the signal under test.

(2) Set the FREQUENCY RESPONSE switch to 50 kHz.

(3) Set the FREQUENCY RANGE switch to suit the carrier frequency of the signal. For detailed instructions on oscillator arrangements, see Sect. 2.10. In this section, it is assumed that the internal local oscillator will be used.

(4) Set the FUNCTION switch to TUNE OSCILLATOR. Adjust the tuning dial to the carrier frequency. Tune for peak deflection and then adjust the RF LEVEL control to give a meter deflection below the AM MAX line in the black RF LEVEL arc, preferably towards the lower end of the arc for best mixing and hence minimum distortion.

(5) Set the FUNCTION switch to AM SET FREQ. Slightly readjust the TUNE FREQUENCY controls until the meter deflects to the SET line. Avoid spurious settings - the correct one is that closest to the original setting obtained in (4).

(6) Set the FUNCTION switch to SET AM. Adjust the adjacent SET AM control until the meter reads on the SET line. Note that this setting can be done with or without modulation since the adjustment is to the mean level of the i.f. signal. However, appreciable even harmonic distortion can affect the setting accuracy and, in such circumstances, it is preferable to set up without modulation.

(7) Set the FUNCTION switch to AM PEAK. Read the percentage modulation depth at the peak.

(8) Set the FUNCTION switch to AM TROUGH. Read the percentage modulation depth at the trough.

When the peak and trough readings are unequal, distortion is present in the input signal.

2.7 MEASURING FM ON AM

To measure the spurious f.m. on an amplitude modulated source, proceed as for f.m. measurement, Sect. 2.5.

A certain amount of spurious f.m. is introduced by the instrument itself. When the carrier is deeply modulated, at high modulating frequencies, this should be taken into consideration, but below 40% depth in the audio range of frequencies the spurious deviation is not very significant. At 80% depth and 1 kHz frequency, the maximum spurious deviation is typically less than 150 Hz referred to the 15 kHz bandwidth.

Tables 2.1 and 2.2 give typical results which should be used for general guidance purposes only.

TABLE 2.1

Spurious deviations with increasing % a.m.

1. RF LEVEL control set for meter reading at the AM MAX line.

2. AM frequency = 1 kHz.

	Spurious deviation	
% a.m.	*15 kHz bandwidth*	*200 kHz bandwidth*
30%	75 Hz	750 Hz
80%	150 Hz	2 kHz

TABLE 2.2

Spurious deviations with increasing a.m. frequency

1. RF LEVEL control set for meter reading at the AM MAX line.

2. AM depth = 80%.

	Spurious deviation	
AM frequency	*15 kHz bandwidth*	*200 kHz bandwidth*
1 kHz	150 Hz	2 kHz
10 kHz	2 kHz	3 kHz
100 kHz		7 kHz

2.8 MEASURING AM ON FM

The modulation meter may be used to indicate amplitude modulation in a frequency modulated signal, provided that the deviation is less than 100 kHz. The procedure is that of a.m. measurement, Sect. 2.6.

In general, the spurious a.m. indication will be proportional to the deviation. The i.f. amplifier is set up for optimum phase response for f.m. deviation measurement rather than a maximally flat response for measuring a.m. on f.m.

Below 100 kHz deviation, the internally generated spurious a.m. is less than 5% approximately.

2.9 NOISE MEASUREMENTS

By connecting an external meter to the OUTPUT socket, noise measurements limited only by the noise level generated within the instrument can be made. The internal meter, being peak reading, is not suitable for measuring noise and, ideally, an r.m.s. responding meter should be used. However, sufficiently accurate results are usually obtained with an average reading meter by applying the appropriate correction factor.

Typical meters which can be used are as follows :

(a) RMS electronic voltmeter capable of measuring to the necessary accuracy (1% of full-scale deviation gives approximately 7.75 mV on any range except 1.5 kHz f.s.d. where the level is about 2.45 mV). Errors due to crest factor and zero shift can be avoided by operating the meter at mid-scale by means of an attenuator.

(b) Marconi Instruments Sensitive Valve Voltmeter, type TF 2600.

(c) Marconi Instruments Distortion Factor Meter, type TF 2331.

(b) and (c) are average reading and a correction of +1 dB should be applied.

For normal noise measurements the FREQUENCY RESPONSE switch should be in the NOISE position, which gives a 3 dB bandwidth of 50 Hz to 15 kHz (except on the 1.5 kHz deviation range).

For narrow band measurements the DE-EMPHASIS switch can be used to limit the upper frequency; for example, the 50 μs position gives a response of -3 dB at 3.15 kHz. Alternatively, use the 1.5 kHz deviation range which gives a restricted bandwidth of 30 Hz to 3.4 kHz.

For wide band measurements use the 200 kHz position of the FREQUENCY RESPONSE switch and limit the top frequency by a capacitor or filter across the OUTPUT socket. A capacitor of 0.0015 μF gives a response of -3 dB at 200 kHz, or a low-pass filter can be chosen to give the required lower cut-off frequency.

The output of the modulation meter is 0.775 V into 600 Ω for full-scale deflection on the internal meter (0.245 V on the 1.5 kHz deviation range).

For measurements above about 200 MHz the Crystal Oscillator TK 2302 should be used if lowest possible internally generated noise is required. Thus, a crystal suitable for the appropriate frequency must be available.

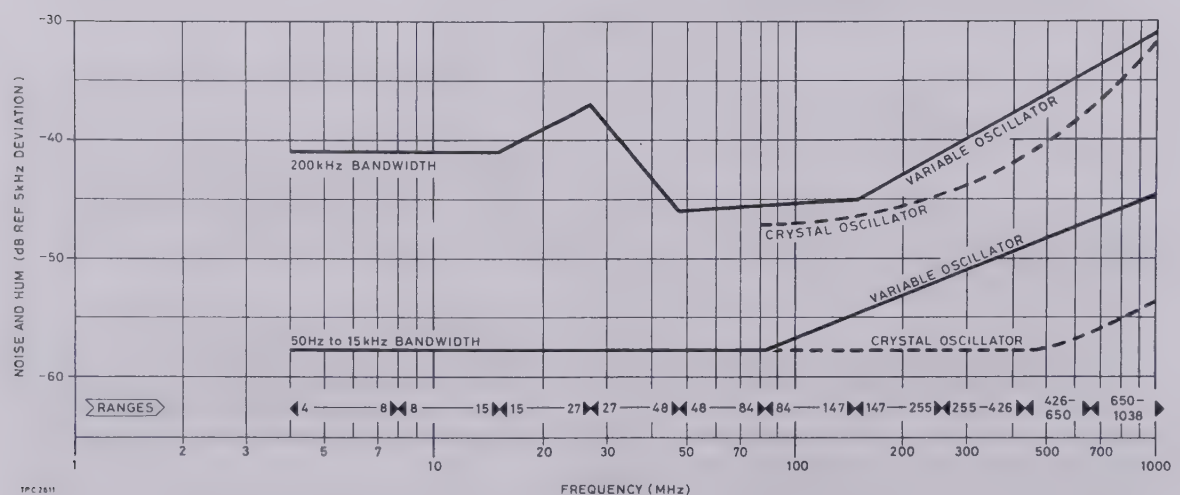


Fig. 2.2 Typical noise level of instrument

The curves given in Fig. 2.2 show typical noise levels produced by the internal oscillator and Crystal Oscillator TK 2302 over the r.f. range of the instrument. In the 'noise' bandwidth, below 100 MHz, there is insignificant difference in respective noise levels. Above 100 MHz, however, the noise level using the internal oscillator increases progressively with frequency, whereas with the crystal oscillator the level remains nearly constant. The necessity to use the crystal oscillator depends on the noise level of the equipment under test and, as shown by the curves, the bandwidth in which the measurement is to be made and the carrier frequency. In the 200 kHz bandwidth, there is little advantage in using the crystal oscillator.

In both bandwidths, crystal control will eliminate oscillator microphony and therefore may be advantageous in conditions of vibration or high acoustic noise levels.

FM noise

(1) Connect an external meter to the OUTPUT socket. Apply r.f. input at a suitable level.

(2) Adjust the tuning dial to the signal frequency and tune for peaking, as in Sect. 2.5 (5). Then adjust the RF LEVEL control for a reading towards the top end of the black arc on the internal meter.

(3) Switch to the appropriate FREQUENCY RESPONSE setting, as described above, thus selecting the required bandwidth. For low noise measurement, particularly on the 200 kHz bandwidth, it is advisable to minimize the inherent noise in the modulation meter by adjusting the RF LEVEL control until minimum noise is indicated on the external meter (even if this causes the meter to deflect beyond full-scale when the FUNCTION switch is at SET LEVEL - see (7)).

(4) Switch to position FM SET FREQ. and adjust the oscillator until the meter reads SET.

(5) Switch to DEV+. Modulate the carrier to the reference deviation and select the appropriate range on the MODULATION RANGE switch.

(6) Read the external meter and record the dB level.

(7) Remove the modulation from the signal under test. Turn the MODULATION RANGE switch to the 5 kHz range and then increase the sensitivity of the external meter to give a convenient reading. Adjust the RF LEVEL control so that this reading is at a minimum. Record the new level, which is given by the reading on the external meter plus 10 dB for each step traversed by the MODULATION RANGE switch.

(8) The signal-to-noise ratio referred to the selected bandwidth in which the measurements were made is given by the difference between the levels measured in (6) and (7).

AM noise

(1) Connect an external meter to the OUTPUT socket. Apply r.f. input at a suitable level.

(2) Adjust the tuning dial to the signal frequency and tune for peaking, as in Sect. 2.6(3). Then adjust the RF LEVEL control to give a meter deflection at the AM MAX mark (or as near to it as possible with a low level input).

(3) Switch to the appropriate FREQUENCY RESPONSE setting, as described above, thus selecting the required bandwidth.

(4) Switch to position AM SET FREQ and adjust the oscillator until the meter reads SET.

(5) Switch to SET AM and adjust the SET AM level control for a meter reading at the SET mark.

(6) Switch to AM PEAK. Modulate the carrier to the reference depth and select the appropriate a.m. range on the MODULATION RANGE switch. Since 100% modulation is impracticable, use some other level and correct the result accordingly, e.g. use 50% modulation and add -6 dB to the noise reading to obtain a result relative to 100% modulation.

(7) Read the external meter and record the dB level.

(8) Remove the modulation from the signal under test. Turn the MODULATION RANGE switch to the 30% range and then increase the sensitivity of the external meter to give a convenient reading. Record the new level, which is given by the reading on the external meter plus 10 dB for each step traversed by the MODULATION RANGE switch.

(9) The signal-to-noise ratio is given by the difference between the levels measured in (6) and (7).

2.10 OSCILLATOR ARRANGEMENTS AND OPERATING NOTES

The same procedure applies for both f.m. and a.m. measurements. The basic requirement is for a stable frequency source 1.5 MHz higher than the signal under test, and this can be obtained from three sources :

(a) The internal variable oscillator usable at all frequencies between 4 and 1200 MHz.

(b) An external oscillator with an output of about 200 mV across 50 Ω.

(c) The optional CRYSTAL OSCILLATOR type TK 2302 - for details see Sect. 2.11.

2.10.1 Internal oscillator

Turn the OSCILLATOR selector to INT, and choose the appropriate range switch.

Adjust the tuning dial with the coarse control to the carrier frequency of the input signal. Then adjust the coarse and/or fine controls for peak meter deflection. Note that there are two tuning points at which the meter peaks, corresponding to local oscillator frequencies 1.5 MHz above and below the input carrier frequency; always tune to the peak at the higher frequency tuning point for correct polarity sense of the FUNCTION switch.

Adjust the fine control from time to time, to bring the meter reading to the SET mark when switched to the SET FREQ position. It is permissible to tune to another internal oscillator harmonic as this will not affect the readings obtained.

The oscillator takes about two minutes to stabilize after turning on, but this is only of any significance at very high frequencies.

2.10.2 External oscillator

If a stable frequency source is available, it may be preferable to use it rather than the internal oscillator. Feed the external oscillator signal into the EXT OSCILLATOR socket and turn the OSCILLATOR switch to EXT. An input level of about 200 mV into 50 Ω is required at a frequency 1.5 MHz above the input signal frequency.

The primary use of this facility is for measurement on r.f. signals which contain harmonics of less than 20 dB down on the fundamental. Because the internal oscillator signal also contains harmonics, mixing two such signals can give rise to spurious results. A 'pure' local oscillator signal minimizes the risk.

Secondly, if an external crystal oscillator is available, it may be preferred to use this, rather than the internal crystal oscillator, for low level noise measurements.

2.10.3 Use above 1200 MHz

It is possible to use the instrument above 1200 MHz using the internal or external oscillator.

With the internal oscillator, higher harmonics are sufficiently present to cover the range 1200 to 1600 MHz at reduced sensitivity. Use the appropriate range with a scale indication of half the wanted frequency; for example, tune to 750 MHz for measurements at 1500 MHz.

Using a suitable external oscillator the carrier frequency range can be extended to about 2500 MHz, but the sensitivity may deteriorate.

2.11 USE OF CRYSTAL OSCILLATOR TK 2302

This section applies only when the instrument includes the optional crystal oscillator unit which fits in the front panel recess. The use of this oscillator is advantageous when making low noise measurements above about 200 MHz, or in conditions likely to cause microphony, or where operation is restricted to a few spot frequencies. Up to three crystals can be plugged in and any one selected by a switch.

2.11.1 Fitting the crystal oscillator

(1) Remove the rectangular cover plate held by four M3 screws to the front panel.

(2) Remove the bottom cover of the instrument.

(3) Insert the crystal oscillator unit in the front panel cut-out.

(4) Connect the coaxial plug and red wander plug to their mating sockets on the housing behind the OSCILLATOR selector.

(5) Secure the unit with the four fixing screws and replace the bottom cover.

2.11.2 Crystal selection

Crystals should be series resonant 3rd overtone types in the range 40 to 60 MHz.

Normal tolerance (200 p.p.m. from 0 to 60 °C) is adequate except at the higher signal frequencies when 150 p.p.m. is recommended. If possible, all crystals should have similar equivalent series resistance, ideally 35 Ω ±5%. If the e.s.r. is substantially different from this, adjustment of the crystal drive may be required by selecting a new value for R8 (increase resistance if e.s.r. is high).

Recommended crystals are :

Range (MHz)	Marconi type
40 to 44.999	QO 1670F/150/A/S
45 to 54.999	QO 1670G/150/A/S
55 to 60	QO 1670K/150/A/S

These crystals are in hermetically sealed, style D miniature cases (US style HC6U).

The required crystal frequency for any r.f. input between 80 and 1000 MHz can be calculated by the following procedure :-

(1) Add 1.5 MHz to the r.f. input frequency to obtain the harmonic frequency of the crystal.

(2) Divide this sum by the crystal harmonic factor given in Table 2.3 against the applicable r.f. input frequency range. The result is the crystal fundamental frequency.

Expressed as a formula :

$$\text{Crystal frequency} = \frac{(\text{RF} + 1.5)\ \text{MHz}}{\text{Harmonic factor}}$$

NOTE. The r.f. input range of 38.5 to 58.5 MHz can also be crystal controlled by operating the crystal on its fundamental frequency (or to 61.5 MHz if positive and negative deviation are reversed).

TABLE 2.3

Crystal harmonic factors

RF input frequency (MHz)	*Crystal harmonic factor*	*Crystal fundamental range*
38.5 - 58.5	1	
80 - 118.5	2	
118.5 - 178.5	3	
178.5 - 238.5	4	
238.5 - 298.5	5	
298.5 - 358.5	6	
358.5 - 418.5	7	
418.5 - 478.5	8	
478.5 - 538.5	9	40 - 60 MHz
538.5 - 598.5	10	
598.5 - 658.5	11	
658.5 - 718.5	12	
718.5 - 778.5	13	
778.5 - 838.5	14	
838.5 - 898.5	15	
898.5 - 958.5	16	
958.5 - 1000	17	

Example : To find the fundamental crystal frequency for an r.f. input of 461.4 MHz.

From Table 2.3, it can be seen that this r.f. is within the range corresponding to a crystal harmonic factor of 8.

$$\text{Therefore crystal frequency} = \frac{461.4 + 1.5}{8}$$

$$= 57.8625\ \text{MHz}.$$

A frequency of 57.86 MHz would be sufficiently precise, having regard to the tolerance of the crystal specification and the bandwidth of the i.f. Crystals are fully specified in Data Sheets QO 1670F, -G and -K to which reference should be made for further details if required. Data sheets and crystals are available from the Marconi Company Ltd., Chelmsford, Essex.

2.11.3 Crystal oscillator operation

(1) Plug in a crystal of the required frequency as selected in Sect. 2.11.2 and turn the CRYSTAL selector to the corresponding position. The capacitances of the crystals in the unused positions affect the adjustment of the oscillator. It is therefore recommended that crystals be inserted in all three positions since the oscillator is set up in the factory with three crystals.

(2) Apply the r.f. input signal at a suitable level.

(3) Turn the FUNCTION switch to position 1 and the OSCILLATOR switch to XTAL.

(4) Adjust the appropriate CRYSTAL TUNE preset for maximum meter deflection. If there is more than one peak, choose the one that gives the best results, e.g. the lowest noise. Thereafter proceed as for internal.

2.12 MEASUREMENT IN 1 TO 2 MHz RANGE

The instrument can accept signals in the band 1 to 2 MHz, applied directly to RF IN, with the oscillator off, i.e. switched to EXT. Input sensitivity is the same as usual. Ensure the modulation frequency does not take the frequency beyond the band limits quoted, so as to avoid introducing distortion caused by the reduced gain outside the pass band.

Operating the instrument in this way cuts out the frequency inversion caused by the heterodyne system normally used. The polarity of the DEV+ and DEV- positions of the FUNCTION switch is therefore reversed.

2.13 ASYMMETRIC MODULATION AND CARRIER SHIFT

The presence of asymmetric modulation usually indicates distortion in the equipment under test, and is revealed by unequal meter readings when the FUNCTION switch is turned between PEAK and TROUGH or DEV+ and DEV-.

In position SET FREQ, the output from a counter circuit in the limiter is measured by the meter. When the meter indicates SET, the i.f. is centred on 1.5 MHz exactly. If modulation then causes the meter reading to fluctuate, carrier shift is present. The extent of the shift may be measured by connecting a counter to IF OUT. In cases of severe carrier shift, the modulation meter must be set up with modulation off.

2.14 USE OF LF OUTPUT SOCKET

CAUTION. Application of d.c. to this socket may damage the associated electrolytic coupling capacitor.

This output enables the modulation waveform on the input signal to be monitored or analysed. It also enables a sensitive external meter to be used to extend the deviation range down to the level of residual noise within the instrument.

The socket is fed by an independent output stage in the 2nd l.f. amplifier and therefore the internal meter is unaffected by loads connected to it.

Depending on the position of the FUNCTION switch, a.m. or f.m. demodulated outputs are obtained. The output impedance is approximately 600 Ω and the open circuit voltage approximately 1.5 V for full-scale deflection on the internal meter. On the 1.5 kHz deviation range the output level will only be 0.1 mW. On the other deviation ranges the output level will be 1 mW.

NOTE. For most purposes, the output can be terminated with 600 Ω or unterminated. In the latter case, a voltage due to leakage in the output coupling capacitor may appear at the output, causing difficulty if a d.c. coupled oscilloscope is used at high sensitivity.

The l.f. response is substantially level up to 200 kHz. The output is also available with switched de-emphasis to restore the modulation characteristic of signals that have had pre-emphasis applied.

2.15 USE OF IF OUTPUT SOCKET

This socket can be used to measure carrier shift by connecting a counter to it - see Sect. 2.13 - or to view the a.m. envelope on an oscilloscope.

It may also be used to measure amplitude modulation above 50 kHz which normally would not be passed by the a.m. detector. This is an extended use of the modulation meter which in practice would probably be limited by the attenuation of the 10 kΩ output resistance and the input capacitance of the measuring instrument.

2.16 FM STEREO MEASUREMENTS

Distortion and channel separation in stereo systems which are designed to meet CCIR Report 293-2 and US Federal Communications Commission (FCC) requirements can be measured with the TF 2300B Modulation Meter. The general procedures are described in the following sections.

2.16.1 Harmonic distortion

It can be assumed that distortion introduced by the modulation meter is small in comparison with that in stereo transmitters, being typically better than 0.1% for deviations up to ±75 kHz and therefore, for practical purposes, can be ignored.

The frequency spectrum of a GE-Zenith type of f.m. stereo signal when a 1 kHz test tone (for example) is applied to the left channel and no signal to the right, is shown in Fig. 2.3.

Ideally, only the fundamental 1 kHz signal in the left + right (L + R) channel and the 37 and 39 kHz sidebands of the suppressed sub-carrier in the L - R channel should be present. In practice, however, harmonic distortions will occur at 2, 3, 4 kHz .... in the L + R channel and at 36 and 40, 35 and 41, 34 and 42 kHz .... in the L - R channel. These are the distortion components which it is desired to measure.

The test arrangement for measuring distortion in an f.m. stereo transmitter is given below :-

(1) Connect the transmitter output to the modulation meter in accordance with Sect. 2.4 - Preparation for use.

(2) Set up the modulation meter with the transmitter signal on, in accordance with Sect. 2.5 - Measuring f.m. deviation.

The following notes are intended to amplify the setting instructions and refer specifically to the GE-Zenith system.

(3) Set the controls as follows :-

MODULATION RANGE : 150 kHz.
FREQUENCY RESPONSE : 200 kHz.
DE-EMPHASIS : OFF, even if pre-emphasis is being applied.
FUNCTION : DEV+ or DEV-.

(4) Apply a test signal of a chosen frequency to the left channel with no signal to the right channel.

(5) Connect Wave Analyser type TF 2330 series, or an equivalent instrument for harmonic analysis of the audio range, to the OUTPUT socket of the modulation meter. (Refer to the instruction manual on the analyser for calibration and measuring procedures.)

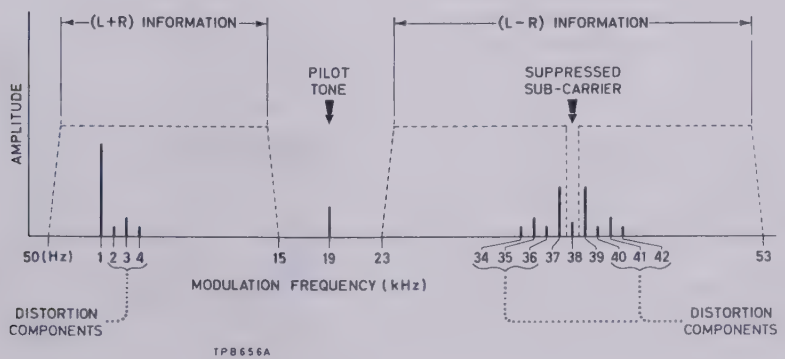


Fig. 2.3 Frequency spectrum of f.m. stereo signal with 1 kHz modulating tone

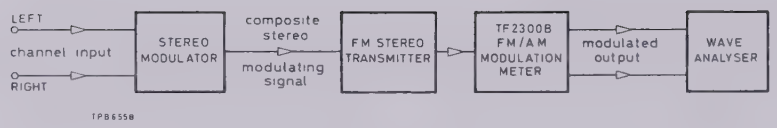


Fig. 2.4 Test arrangement for measuring distortion

(6) The frequency spectrum of the demodulated output of the modulation meter can be obtained by tuning through the frequency range and taking measurements at the appropriate frequencies. The result is usually referred to the fundamental and expressed as percentages or dB readings, calculated by the usual method for harmonic distortion measurement as described in the wave analyser manual.

For practical working purposes, the small amount of distortion introduced by the modulation meter can be neglected.

2.16.2 Channel separation

If it were possible to view the 50 Hz to 15 kHz and the 23 to 53 kHz regions of Fig. 2.3 separately, the waveforms shown in Figs. 2.5(a) and (b) would be seen.

The ideal composite modulating signal with the 19 kHz pilot tone removed should be the sum of these waveforms as shown in (c). In practice, there will be amplitude unbalance and relative phase shift (group delay error) between the two added signals. These two effects, which can be viewed on a direct coupled oscilloscope, are illustrated in (d) and (e), where amplitude 'B' represents a signal on the right channel due to an input on the left channel.

Channel separation is given by :

$$\text{Separation} = 20 \log_{10} \frac{A}{B} \quad \ldots\ldots \quad (1)$$

where A and B are measurements indicated in Figs. 2.5(d) and (e).

An f.m. stereo transmitter or stereo modulator must meet specified requirements as regards response and phase shift. In the FCC requirements, it is deemed that these are met if the channel separation exceeds 29.7 dB.

A suitable oscilloscope, such as a Marconi Instruments type TF 2210, connected to the OUTPUT socket of the modulation meter, enables the channel separation to be measured.

From 200 Hz to 15 kHz, the channel separation figure of the modulation meter is typically 14 dB below the minimum required of f.m. stereo channels in the FCC regulations, while at 50 Hz (the worst condition), it is typically 10 dB below.

The test arrangement for measuring channel separation is as illustrated in Fig. 2.4, except that the wave analyser is now replaced by an oscilloscope, and the procedure is as follows :-

(1) Set up the equipment and modulation meter as already described for distortion measurements.

(2) Apply a test signal to the left channel at 15 kHz modulation frequency (for example) with no signal on the right channel.

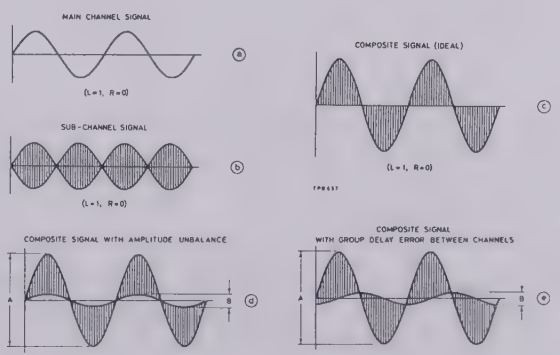


Fig. 2.5 Derivation of composite stereo signal showing unbalance and phase shift errors

(3) Connect the oscilloscope, switched to d.c. coupling, to the OUTPUT socket of the modulation meter. If the oscilloscope has a high input resistance it is advisable to connect a resistor of about 1 kΩ (the exact value is unimportant) in parallel with the oscilloscope input; this is to prevent leakage in the electrolytic output coupling capacitor of the modulation meter from producing a voltage which may shift the trace off the screen. Adjust the oscilloscope to suitable time base and input attenuator settings for a composite signal waveform. The procedure here depends on the equipment being tested; in general it consists of setting up the system for deviation, and gain etc., in accordance with individual system manufacturers' instructions until a satisfactory waveform is seen. The gain of the L-R channel should then be adjusted for minimum amplitude 'B'. Measure this amplitude and calculate separation in accordance with formula (1).

2.17 PHASE MODULATION

To find the degree of phase modulation, measure the deviation and divide by the modulating frequency to obtain the answer in radians.

2.18 TELEMETRY DEVIATION

To measure the deviations in a modulated telemetry signal connect the OUTPUT socket to the external meter via a switched series of band-pass filters at the sub-carrier frequencies. This enables the deviation due to each tone to be measured, having first calibrated the meter against a signal modulated by a single tone.

Decibel conversion table

Ratio Down			Ratio Up	
VOLTAGE	POWER	DECIBELS	VOLTAGE	POWER
1·0	1·0	**.0**	1·0	1·0
·9886	·9772	**.1**	1·012	1·023
·9772	·9550	**·2**	1·023	1·047
·9661	·9333	**·3**	1·035	1·072
·9550	·9120	**·4**	1·047	1·096
·9441	·8913	**·5**	1·059	1·122
·9333	·8710	**·6**	1·072	1·148
·9226	·8511	**·7**	1·084	1·175
·9120	·8318	**·8**	1·096	1·202
·9016	·8128	**·9**	1·109	1·230
·8913	·7943	**1·0**	1·122	1·259
·8710	·7586	**1·2**	1·148	1·318
·8511	·7244	**1·4**	1·175	1·380
·8318	·6918	**1·6**	1·202	1·445
·8128	·6607	**1·8**	1·230	1·514
·7943	·6310	**2·0**	1·259	1·585
·7762	·6026	**2·2**	1·288	1·660
·7586	·5754	**2·4**	1·318	1·738
·7413	·5495	**2·6**	1·349	1·820
·7244	·5248	**2·8**	1·380	1·905
·7079	·5012	**3·0**	1·413	1·995
·6683	·4467	**3·5**	1·496	2·239
·6310	·3981	**4·0**	1·585	2·512
·5957	·3548	**4·5**	1·679	2·818
·5623	·3162	**5·0**	1·778	3·162
·5309	·2818	**5·5**	1·884	3·548
·5012	·2512	**6**	1·995	3·981
·4467	·1995	**7**	2·239	5·012
·3981	·1585	**8**	2·512	6·310
·3548	·1259	**9**	2·818	7·943
·3162	·1000	**10**	3·162	10·000
·2818	·07943	**11**	3·548	12·59
·2512	·06310	**12**	3·981	15·85
·2239	·05012	**13**	4·467	19·95
·1995	·03981	**14**	5·012	25·12
·1778	·03162	**15**	5·623	31·62

Decibel conversion table (*continued*)

Ratio Down			Ratio up	
VOLTAGE	*POWER*	*DECIBELS*	*VOLTAGE*	*POWER*
·1585	·02512	**16**	6·310	39·81
·1413	·01995	**17**	7·079	50·12
·1259	·01585	**18**	7·943	63·10
·1122	·01259	**19**	8·913	79·43
·1000	·01000	**20**	10·000	100·00
·07943	$6{\cdot}310 \times 10^{-3}$	**22**	12·59	158·5
·06310	$3{\cdot}981 \times 10^{-3}$	**24**	15·85	251·2
·05012	$2{\cdot}512 \times 10^{-3}$	**26**	19·95	398·1
·03981	$1{\cdot}585 \times 10^{-3}$	**28**	25·12	631·0
·03162	$1{\cdot}000 \times 10^{-3}$	**30**	31·62	1,000
·02512	$6{\cdot}310 \times 10^{-4}$	**32**	39·81	$1{\cdot}585 \times 10^{3}$
·01995	$3{\cdot}981 \times 10^{-4}$	**34**	50·12	$2{\cdot}512 \times 10^{3}$
·01585	$2{\cdot}512 \times 10^{-4}$	**36**	63·10	$3{\cdot}981 \times 10^{3}$
·01259	$1{\cdot}585 \times 10^{-4}$	**38**	79·43	$6{\cdot}310 \times 10^{3}$
·01000	$1{\cdot}000 \times 10^{-4}$	**40**	100·00	$1{\cdot}000 \times 10^{4}$
$7{\cdot}943 \times 10^{-3}$	$6{\cdot}310 \times 10^{-5}$	**42**	125·9	$1{\cdot}585 \times 10^{4}$
$6{\cdot}310 \times 10^{-3}$	$3{\cdot}981 \times 10^{-5}$	**44**	158·5	$2{\cdot}512 \times 10^{4}$
$5{\cdot}012 \times 10^{-3}$	$2{\cdot}512 \times 10^{-5}$	**46**	199·5	$3{\cdot}981 \times 10^{4}$
$3{\cdot}981 \times 10^{-3}$	$1{\cdot}585 \times 10^{-5}$	**48**	251·2	$6{\cdot}310 \times 10^{4}$
$3{\cdot}162 \times 10^{-3}$	$1{\cdot}000 \times 10^{-5}$	**50**	316·2	$1{\cdot}000 \times 10^{5}$
$2{\cdot}512 \times 10^{-3}$	$6{\cdot}310 \times 10^{-6}$	**52**	398·1	$1{\cdot}585 \times 10^{5}$
$1{\cdot}995 \times 10^{-3}$	$3{\cdot}981 \times 10^{-6}$	**54**	501·2	$2{\cdot}512 \times 10^{5}$
$1{\cdot}585 \times 10^{-3}$	$2{\cdot}512 \times 10^{-6}$	**56**	631·0	$3{\cdot}981 \times 10^{5}$
$1{\cdot}259 \times 10^{-3}$	$1{\cdot}585 \times 10^{-6}$	**58**	794·3	$6{\cdot}310 \times 10^{5}$
$1{\cdot}000 \times 10^{-3}$	$1{\cdot}000 \times 10^{-6}$	**60**	1,000	$1{\cdot}000 \times 10^{6}$
$5{\cdot}623 \times 10^{-4}$	$3{\cdot}162 \times 10^{-7}$	**65**	$1{\cdot}778 \times 10^{3}$	$3{\cdot}162 \times 10^{6}$
$3{\cdot}162 \times 10^{-4}$	$1{\cdot}000 \times 10^{-7}$	**70**	$3{\cdot}162 \times 10^{3}$	$1{\cdot}000 \times 10^{7}$
$1{\cdot}778 \times 10^{-4}$	$3{\cdot}162 \times 10^{-8}$	**75**	$5{\cdot}623 \times 10^{3}$	$3{\cdot}162 \times 10^{7}$
$1{\cdot}000 \times 10^{-4}$	$1{\cdot}000 \times 10^{-8}$	**80**	$1{\cdot}000 \times 10^{4}$	$1{\cdot}000 \times 10^{8}$
$5{\cdot}623 \times 10^{-5}$	$3{\cdot}162 \times 10^{-9}$	**85**	$1{\cdot}778 \times 10^{4}$	$3{\cdot}162 \times 10^{8}$
$3{\cdot}162 \times 10^{-5}$	$1{\cdot}000 \times 10^{-9}$	**90**	$3{\cdot}162 \times 10^{4}$	$1{\cdot}000 \times 10^{9}$
$1{\cdot}000 \times 10^{-5}$	$1{\cdot}000 \times 10^{-10}$	**100**	$1{\cdot}000 \times 10^{5}$	$1{\cdot}000 \times 10^{10}$
$3{\cdot}162 \times 10^{-6}$	$1{\cdot}000 \times 10^{-11}$	**110**	$3{\cdot}162 \times 10^{5}$	$1{\cdot}000 \times 10^{11}$
$1{\cdot}000 \times 10^{-6}$	$1{\cdot}000 \times 10^{-12}$	**120**	$1{\cdot}000 \times 10^{6}$	$1{\cdot}000 \times 10^{12}$
$3{\cdot}162 \times 10^{-7}$	$1{\cdot}000 \times 10^{-13}$	**130**	$3{\cdot}162 \times 10^{6}$	$1{\cdot}000 \times 10^{13}$
$1{\cdot}000 \times 10^{-7}$	$1{\cdot}000 \times 10^{-14}$	**140**	$1{\cdot}000 \times 10^{7}$	$1{\cdot}000 \times 10^{14}$

Chapter 3

Technical description

3.1 INTRODUCTION

The following description should be read in conjunction with the block diagram, Fig. 3.1, and the circuit diagrams, Chap. 7.

The circuit is summarized in Sect. 3.2 and then each unit is described in Sect. 3.3 to Sect. 3.16.

3.2 CIRCUIT SUMMARY

The signal to the RF IN socket is fed to a mixer (Unit A1 - see Sect. 3.3) where it is heterodyned with the output from a local oscillator. The local oscillator is an accessory crystal oscillator (TK 2302 - see Sect. 3.16), internal oscillator (Units A2, A2a and A2b - see Sect. 3.4) or external oscillator connected to the EXT OSCILLATOR socket, according to the setting of the OSCILLATOR switch (Unit A15).

The output from the mixer is fed to an i.f. amplifier (Unit A3 - see Sect. 3.5) which has a linear phase/frequency response to f.m. The i.f. signal is fed to the IF OUT socket and to a limiter (Unit A4 - see Sect. 3.6) for f.m. or a detector (Unit A11 - see Sect. 3.13) for a.m. according to the setting of the FUNCTION switch. The signal to the a.m. detector is fed through a variable resistor R1, the SET AM level control.

The limiter is followed by a discriminator (Unit A5 - see Sect. 3.7). Alternatively, the output from a calibrator (Unit A12 - see Sect. 3.14) is fed to the discriminator when the FUNCTION switch is at SET CAL. The output from the discriminator is fed through a 200 kHz low-pass filter (Unit A6 - see Sect. 3.8), an l.f. amplifier (Unit A7 - see Sect. 3.9) and, when the FREQUENCY RESPONSE and FUNCTION switches are set accordingly, a 15 kHz low-pass filter (Unit A8 - see Sect. 3.10).

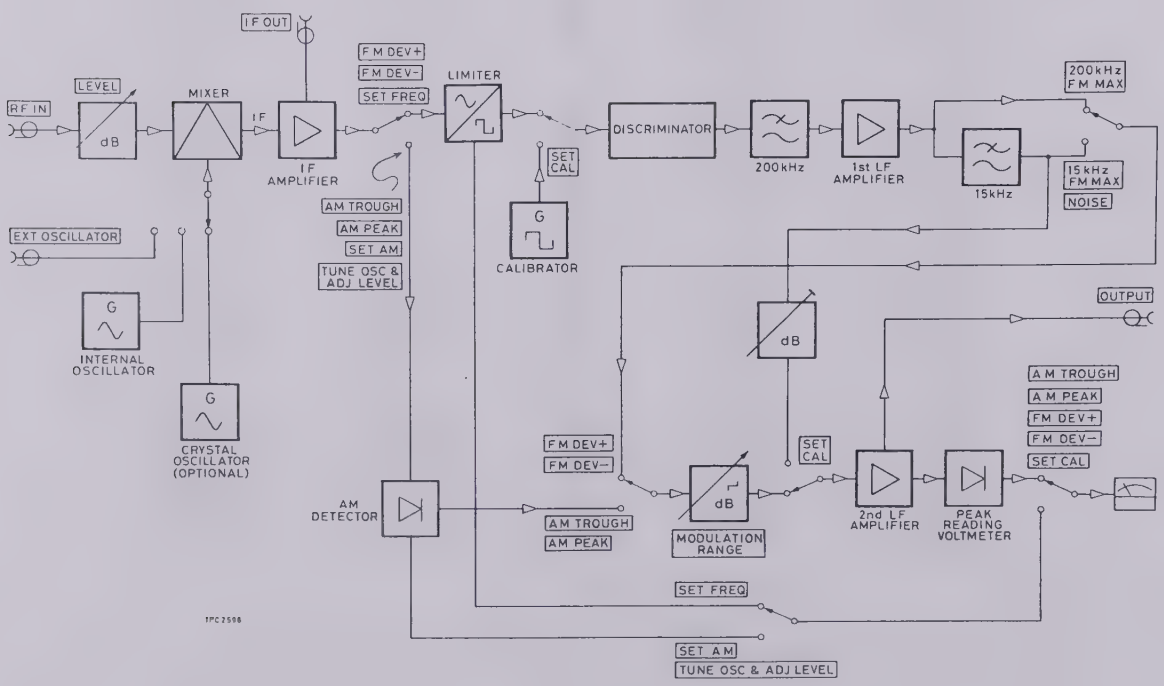


Fig. 3.1 Block diagram

According to the setting of the FUNCTION switch, the 15 kHz low-pass filter (or the lst l.f. amplifier) for f.m. or the detector for a.m. is connected to an attenuator on the MODULATION RANGE switch SC (on Unit A0). The attenuator consists of one 10 dB and two 20 dB Π sections which are switched in as appropriate. The second 20 dB section contains two preset resistors R2 and R4 for adjusting the deviation reading on the 150 and 500 kHz ranges. When the FUNCTION switch is at SET CAL, the range attenuator is replaced by a Π network containing a preset resistor R3 (on Unit A0) for adjusting the level from the calibrator.

The range attenuator is connected to the previous stage through a capacitor C14 on the FREQUENCY RESPONSE switch SE. C14 gives a 50 Hz high-pass response on the NOISE setting.

After the range attenuator is another l.f. amplifier (Unit A9 - see Sect. 3.11) followed by a peak reading voltmeter (Unit A10 - see Sect. 3.12). When the MODULATION RANGE switch is set to 1.5 kHz, the output to the peak reading voltmeter is from the final stage of the l.f. amplifier. For other settings, the output is from the first stage.

Connected across the output of the first stage of the 2nd l.f. amplifier are three capacitors C5, C6 and C12 on the DE-EMPHASIS switch SD, giving the appropriate low-pass characteristic. Also connected across the output of the first stage is a capacitor C13 on the FREQUENCY RESPONSE switch SE. C13 gives a 15 kHz low-pass response on the NOISE setting.

3.3 MIXER—UNIT A1

(Circuit diagram: Fig. 7.2)

The mixer is a conventional, untuned, square law type using a point contact silicon diode MR1. The output is at an i.f. of 1.5 MHz.

The mixer is preceded by an r.f. attenuator AT1, the RF LEVEL control, which gives 6 to 65 dB attenuation at an input impedance of 50 Ω.

3.4 LOCAL OSCILLATOR—UNITS A2, A2a, AND A2b

(Circuit diagram: Fig. 7.2)

There are four oscillator circuits having coverages of $\sqrt{3}$:1 with frequencies of 5.5 to 9.5, 9.5 to 16.5, 49.5 to 85.5 and 85.5 to 148.5 MHz. The eleven ranges are covered by using harmonics as shown in Table 3.1. The last four ranges are covered by using less than the $\sqrt{3}$:1 ratio.

The oscillator circuits each consist of a single f.e.t. TR1, TR2, TR3 or TR4 (on Unit A2a) tuned by means of a coil L1, L2, L3 or L4 and several varactor diodes in parallel. The voltage to the varactors is determined by the coarse TUNE FREQUENCY control R1 (on Unit A2), the fine TUNE FREQUENCY control R6 (on Unit A0) and the preset controls R1 to R16 (on Unit A2b). R1 to R16 are for trimming the oscillator ranges to fit the tuning dial. Power is supplied to the required oscillator circuit according to the setting of the FREQUENCY RANGE switch SA (on Unit A2).

The oscillator circuits are followed by a buffer amplifier (on Unit A2a) which consists of a single transistor TR5. Distortion is introduced deliberately to provide good harmonic outputs.

There is a diode D1, D2, D3 or D4 between each oscillator circuit and the buffer amplifier. When the power is on, the diode is forward biased and the signal is allowed to pass through.

TABLE 3.1

Frequency coverage of internal oscillator

Carrier frequency (MHz)	*Oscillator*	*Harmonic*	*Oscillator frequency (MHz)*
4-8	TR1	1st	5.5-9.5
8-15	TR2	1st	9.5-16.5
15-27	TR1	3rd	16.5-28.5
27-48	TR2	3rd	28.5-49.5
48-84	TR3	1st	49.5-85.5
84-147	TR4	1st	85.5-148.5
147-255	TR3	3rd	148.5-256.5
255-426	TR4	3rd	256.5-427.5
426-650	TR4	5th	427.5-651.5
650-1038	TR4	7th	651.5-1039.5
1038-1200	TR4	8th	1039.5-1201.5

3.5 IF AMPLIFIER—UNIT A3

(Circuit diagram: Fig. 7.2)

The i.f. amplifier consists of three stages, each of two transistors, the stages being coupled by band-pass filters. No limiting occurs in the amplifier. Linearity, frequency response and an overall gain of 50 dB are stabilized by negative feedback in each stage.

3.6 LIMITER—UNIT A4

(Circuit diagram: Fig. 7.3)

The limiter consists of three stages, each of two emitter-coupled transistors, arranged so that signal amplitudes above a certain level are limited. The emitters are connected to preset resistors to equalize the excursion in each direction.

Part of the i.f. signal is tapped off from the third stage to a differentiating capacitor C7 and inductor L1 and then to a detector MR1 to produce uni-directional pulses as shown in Fig. 3.2. The mean d.c. component V_m is almost proportional to the repetition frequency. When the FUNCTION switch is set to SET FREQ, this d.c. is fed to the meter which reads SET when the i.f. is correct.

3.7 DISCRIMINATOR—UNIT A5

(Circuit diagram: Fig. 7.3)

The first stage of the pulse counter type discriminator is a trigger amplifier VT1 which precedes a Schmitt trigger VT2 and VT3. This produces a large square wave output with constant rise and fall times. The collector voltage of VT1 is set by means of a preset resistor RV1 so that the Schmitt trigger is close to the point of regeneration.

The square wave is fed to a differentiating capacitor C4 and then to a pulse generator VT4 and VT5. This produces positive-going pulses which are clipped by the next transistor VT6. The emitter of VT6 is taken to the -12V line so that it clips the bases of the positive-going pulses, thus maintaining constant amplitude.

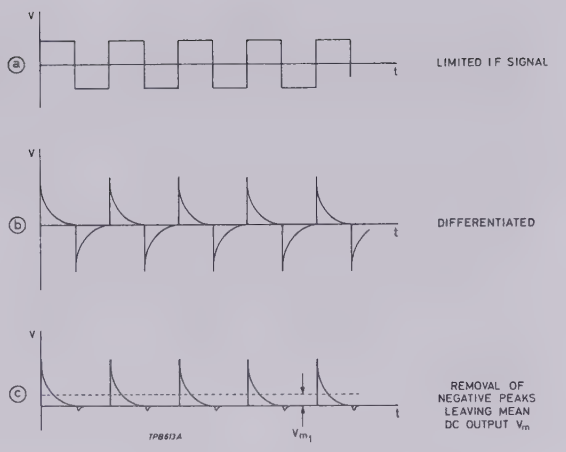


Fig. 3.2 Operation of limiter

A pulse of fixed amplitude and width is generated every time the i.f. signal passes through zero in the positive-going sense as shown in Fig. 3.3. At any given repetition frequency, these pulses have a constant mean amplitude V_m. Therefore V_m will vary directly as the deviation.

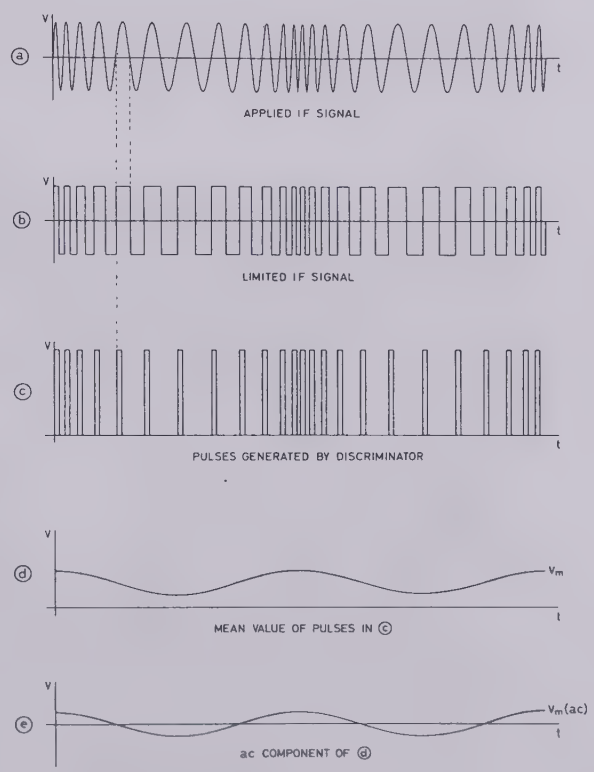


Fig. 3.3 FM demodulation

The output stage is an emitter follower VT7 which, unlike VT6, is conducting continuously and presents a constant low impedance to the following 200 kHz low-pass filter.

3.8 200 kHz LOW-PASS FILTER—UNIT A6

(Circuit diagram: Fig. 7.3)

This filter has a response 3 dB down at 250 kHz to give optimum flatness up to 200 kHz. The filter integrates the pulses from the discriminator, as shown in Fig. 3.3 and rejects the i.f. signal. This produces a voltage which is proportional in amplitude to the deviation.

In order to accommodate the channel separation requirements of stereo broadcast monitoring, the filter design is such as to provide a linear phase frequency response over the appropriate part of the frequency range.

3.9 1st LF AMPLIFIER—UNIT A7

(Circuit diagram: Fig. 7.3)

The amplifier has high stability, wide bandwidth and constant gain. It consists of a current feedback pair VT1 and VT2 followed by a composite emitter follower VT3 and VT4 which has a very low output impedance. Increased gain is provided by positive feedback through a capacitor C6. DC bias is taken to the first stage through a resistor R8. AC negative feedback is taken to the first stage through R8 and also through a capacitor C5, a resistor R7 and a preset resistor R5 (on Unit A0). R5 is the SET CAL FM preset by which the gain is adjusted. Initially, the gain is adjusted so that a known input deviation gives the correct reading. Whenever necessary, the gain is re-adjusted using the calibrator when the FUNCTION switch is set to SET CAL.

The output impedance is due almost entirely to a resistor R14 which matches the 15 kHz low-pass filter. The input impedance is due almost entirely to a resistor R2 which matches the 200 kHz low-pass filter.

3.10 15 kHz LOW-PASS FILTER—UNIT A8

(Circuit diagram: Fig. 7.3)

This filter has a response 3 dB down at 28 kHz to give optimum flatness up to 15 kHz. The filter restricts the bandwidth to the audio range.

When the FUNCTION switch is set to DEV+ or DEV–, the filter is in circuit when the FREQUENCY RESPONSE switch is set to 15 kHz FM MAX or to NOISE. The filter is by-passed by a resistor R26 (on Unit A0) when the FREQUENCY RESPONSE switch is set to 200 kHz FM MAX. The filter is also in circuit when the FUNCTION switch is set to SET CAL in order to prevent high frequency ringing due to the use of a square wave for calibration.

3.11 2nd LF AMPLIFIER—UNIT A9

(Circuit diagram: Fig. 7.4)

This unit is similar to the lst l.f. amplifier, also having high stability, wide bandwidth, constant gain and immunity from supply changes.

The first stage is a current feedback pair VT1 and VT2. Increased gain is provided by positive feedback through a capacitor C6. DC bias is taken to VT1 through a resistor R7. AC negative feedback is taken to VT1 through R7 and also through a capacitor C4, a resistor R8 and a preset resistor RV1 for adjusting the gain. When the MODULATION RANGE switch is set to other than 1.5 kHz, the output for the meter is taken from this stage.

The second stage is another current feedback pair VT3 and VT4. Increased gain is provided by positive feedback through a capacitor C10. DC bias and a.c. negative feedback is taken to VT3 through a resistor R16.

The final stage is a composite emitter follower VT5 and VT6 which has a very low output impedance. When the MODULATION RANGE switch is set to 1.5 kHz, the output for the meter is taken from this stage. The OUTPUT socket is connected to this stage.

The output impedance is due almost entirely to a resistor R22 which matches the external load. The input impedance is due almost entirely to a resistor R2 which matches the range attenuator.

3.12 PEAK READING VOLTMETER—UNIT A10

(Circuit diagram: Fig. 7.4)

The first stage is an amplifier VT1, with negative feedback through a resistor R3, directly coupled to an emitter follower VT2. The output from VT2 is fed through a preset resistor RV1, for adjusting the gain, to a current feedback pair VT3 and VT4. Increased gain is provided by positive feedback through a capacitor C6. DC bias is taken to VT3 through a resistor R12. AC negative feedback is taken to VT3 through R12 and also through a capacitor C14 and a resistor R24.

The output from VT4 is fed to the input of another current feedback pair VT5 and VT6 which have the same circuit as VT3 and VT4 except that negative feedback through a resistor R19 gives unity gain. VT5 and VT6 therefore act as an inverter so that the outputs from VT4 and VT5 are in push-pull.

The push-pull outputs are fed through a rectifier MR1 to a capacitor C8 which charges up to the peak voltage. Across C8 is connected the meter M1 (on Unit A0) in series with a resistor R15. MR1, C8, M1 and R15 are connected as appropriate according to the setting of the FUNCTION switch.

3.13 AM DETECTOR—UNIT A11

(Circuit diagram: Fig. 7.5)

The signal from the i.f. amplifier is fed to a common-emitter amplifier VT1 which is directly coupled to a composite emitter follower VT2 and VT3. Feedback is taken from VT2 and VT3 to VT1 through two resistors R7 and R6.

The output from VT3 is fed to a parallel tuned circuit L1 and C4 and to a diode detector MR1. L1 and C4 distort the signal to compensate for the non-linearity of MR1 so that the differences in readings between peak and trough are minimal. MR1 is biased by means of a resistor R14. This bias causes the meter to read below zero for a zero input when the FUNCTION switch is at SET AM.

MR1 operates into a resistive load R10 and R12. The voltage developed across R12 is fed through a further resistor R13 to a 50 kHz low pass filter consisting of two Π networks C6, C7, L2 and C8, C9, L3.

A resistor R11 is connected to MR1 so that, when the FUNCTION switch is set to TUNE OSCILLATOR, the d.c. output component is fed to the meter which reads a maximum when the tuning is correct.

3.14 CALIBRATOR—UNIT A12

(Circuit diagram: Fig. 7.5)

The output from a multivibrator VT1 and VT2, running at approximately 4 kHz, is fed through a coupling capacitor C6 and resistor R8 to an emitter follower VT4. The square wave from the multivibrator is therefore differentiated and then the negative spikes are clipped. The positive spikes at exactly equal time intervals are fed to a bistable VT7 and VT8 which produces a 2 kHz (approximately) square wave with a mark to space ratio of exactly 1:1.

A crystal XL1 accurately controls at 400 kHz the frequency of an oscillator VT3.

The 2 kHz square wave from the bistable and the 400 kHz sine wave from the oscillator are fed to a gate VT5 and VT6 so that the output is bursts of 400 kHz at a repetition rate of 2 kHz. This has the same effect on the discriminator as an i.f. having a deviation of ±200 kHz except that the mean d.c. component is proportional to 200 kHz instead of to 1.5 MHz.

Power is supplied to the calibrator only when the FUNCTION switch is set to SET CAL.

3.15 POWER SUPPLY—UNIT A13

(Circuit diagram: Fig. 7.6)

The mains supply is fed from the supply plug PL1 through an interference suppressor FL1, the SUPPLY switch SA (on Unit A0), the mains fuse FS1 and the mains voltage selector SA to the primary of a transformer T1 with the supply lamp LP1 (on Unit A0) across one of the two windings.

For the -18 V supply, a pair of the secondary windings is connected to a diode bridge D5 to D8 with a reservoir capacitor C15. The rectified supply is fed to a regulator IC3 with a pass power transistor TR4. The voltage is adjusted by means of a preset resistor R3. Ripple is reduced by means of a filter R6 and C6. Extra reference smoothing is provided by a capacitor C3.

For the -12 V supply, the -18 V supply is fed to a further regulator IC4 with a complementary pair pass power transistors TR1 and TR3. The voltage is adjusted by means of a preset resistor R11. Noise is reduced by means of a capacitor C13. Extra reference smoothing is provided by a capacitor C12.

For the +16.5 V supply, a pair of the secondary windings is connected to a diode bridge D1 to D4 with a reservoir capacitor C14. The rectified supply is fed to a regulator IC1 with a pass power transistor TR2. The voltage is adjusted by means of a preset resistor R17. Ripple is reduced by means of a filter R20 and C9. Extra reference smoothing is provided by a capacitor C3.

3.16 CRYSTAL OSCILLATOR—TK 2302

(Circuit diagram: Fig. 7.2)

The oscillator stage is a common-base transistor TR1 with an inductive collector load L1 and positive feedback through a crystal XL1, XL2 or XL3 according to the setting of the CRYSTAL switch. L1 is tuned by four varactor diodes D1 to D4 so that the crystal oscillates at the correct overtone. D1 to D4 are controlled by preset resistors R1, R2 and R3 according to the setting of the CRYSTAL switch.

Following the oscillator stage is a harmonic generator consisting of two common-base transistors TR2 and TR3 operating under class 'C' conditions. This produces a very 'spikey' output containing harmonics up to 1000 MHz.

Chapter 4

Maintenance

4.1 INTRODUCTION

This section contains information for keeping the equipment in good working order and for checking its overall performance.

CAUTION. This instrument uses semiconductor devices which, although having inherent long term reliability and mechanical ruggedness, are susceptible to damage by overloading, reversed polarity and excessive heat or radiation. Avoid hazards such as reversal of batteries, prolonged soldering, strong r.f. fields or other forms of radiation, use of insulation testers or accidentally applied short circuits. Even the leakage current from an unearthed soldering iron could cause trouble. Before shorting or breaking any circuit, refer to the circuit diagrams to establish the effect on bias arrangements of the transistors.

Screw fasteners

Screw threads used on this instrument are mainly M2, M3 and M4 sizes. These are chromium plated or dyed blue. There are also some BA sizes on the main chassis.

Cruciform headed screws are of the Phillips Pozidriv pattern; to avoid damaging them a Pozidriv screwdriver should be used.

4.2 ACCESS AND LAYOUT

The case is in two sections. The top cover and the bottom cover are each secured by four screws in the sides of the instrument.

Figs. 4.1 and 4.2 show the general location of all units above and below the chassis. Components may be identified by markings on the boards and chassis. For replacement of sub-assemblies and components, see Sects. 5.5 and 5.6.

4.3 PERFORMANCE CHECKS

The tests in this section may be used as a routine maintenance procedure to verify the main performance parameters of the instrument. All tests can be completed without removing the case, except where some internal readjustment is indicated. Tests may be done at any convenient frequency within the carrier range of the modulation meter provided that this frequency is also within the range of the test equipment items a, b, c, d and g.

Many of the methods in this section are simplified and of restricted range compared with those which would be needed to demonstrate complete compliance with the specification. They should be regarded only as providing a check procedure, for use during routine maintenance, to determine whether repair is needed.

4.3.1 Test equipment required

See Table 4.1.

4.3.2 RF input and i.f. output

Test equipment : items a, d, e and l.

This procedure verifies the sensitivity of the modulation meter and the adjustment of the local oscillator.

RF input resistance

(1) Turn the RF LEVEL control mid-way. Connect the multimeter, set for resistance measurement, between the centre pin of the RF IN socket and earth and check that the reading is 50 Ω ±10 Ω.

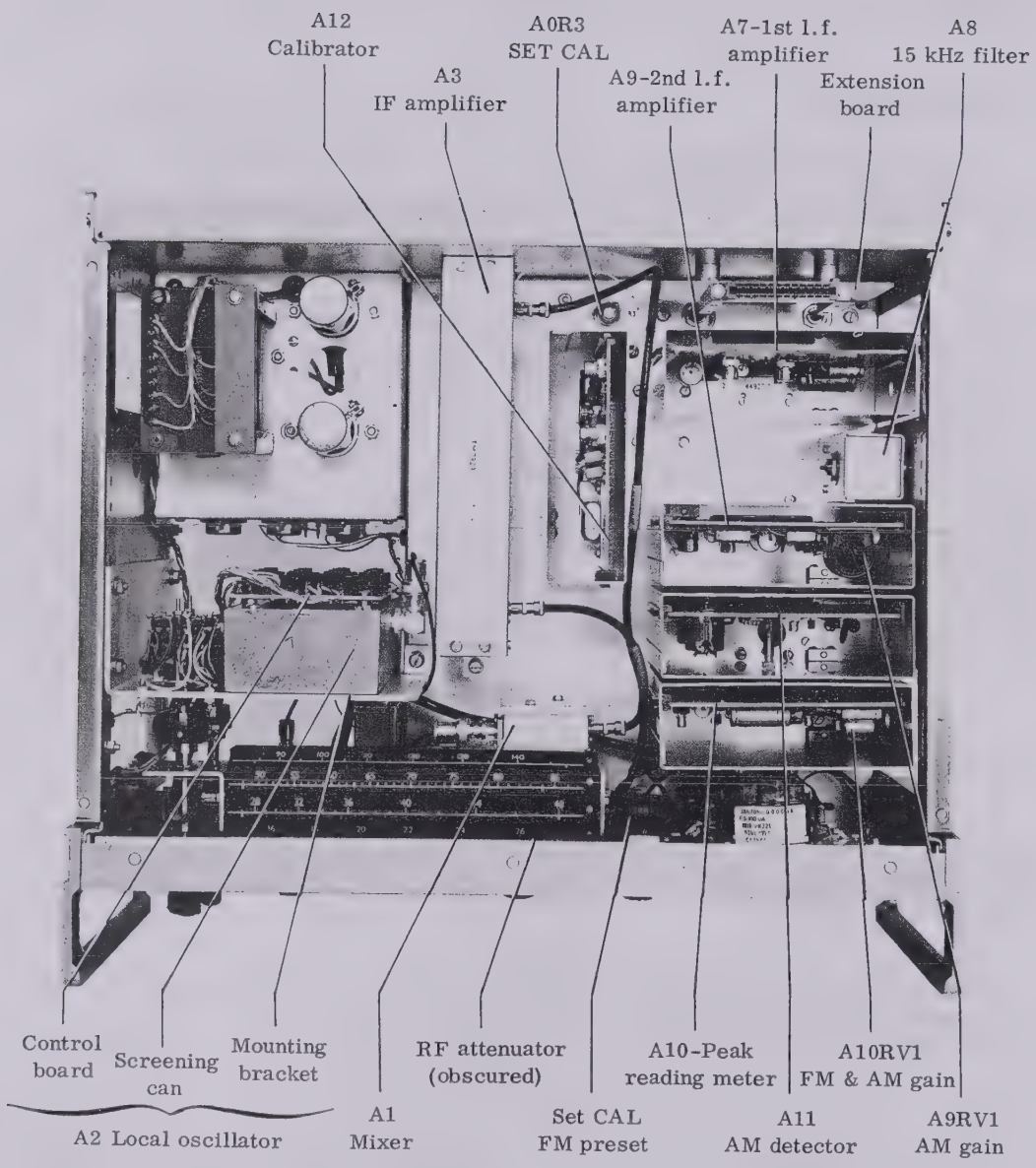


Fig. 4.1 Location of units (top)

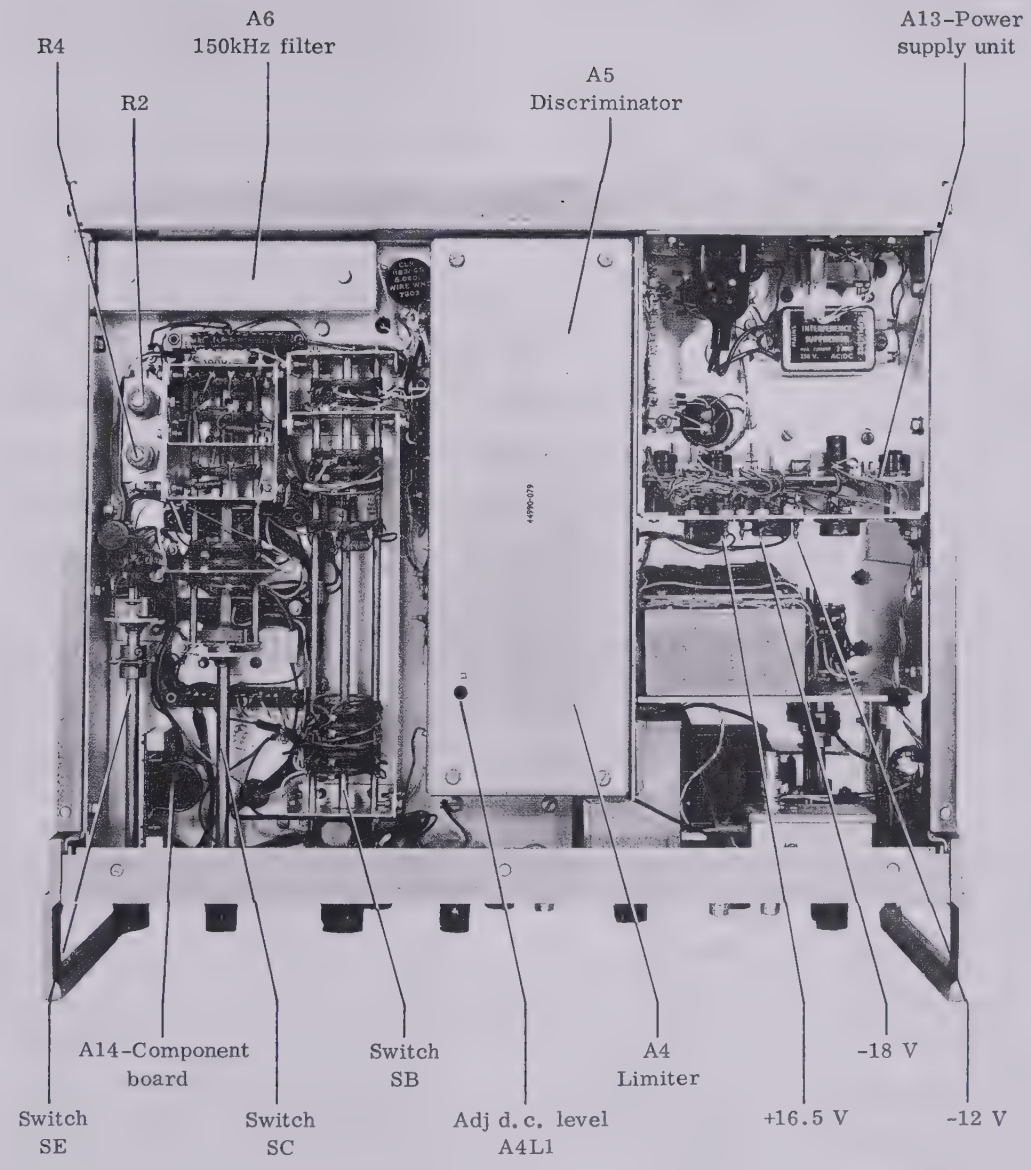


Fig. 4.2 Location of units (bottom)

RF sensitivity

(2) Adjust the signal generator to give a c.w. output of about 50 mV and connect it to the RF IN socket of the modulation meter and to the voltmeter, keeping the leads as short as possible.

(3) On the modulation meter, turn the FREQUENCY RANGE switch and TUNE FREQUENCY controls to suit the r.f. input frequency, the FUNCTION switch to TUNE OSCILLATOR AND ADJUST LEVEL and the RF LEVEL control fully clockwise.

(4) Tune for peak meter deflection and then adjust the signal generator output until the meter deflection is at the bottom of the black arc.

(5) Check that the signal generator output, as indicated on the voltmeter, is within the figure given for r.f. input sensitivity in Sect. 1.2 - Data Summary.

TABLE 4.1

Item	*Type*	*Minimum specification*	*Recommended model*
a	AM signal generator	Output : 100 mV across 50 Ω AM : up to 80% Envelope distortion : 1% at 50% mod.	TF 2002 series
b	FM signal generator	Deviation : up to 250 kHz Mod. freq. : up to 150 kHz	TF 995B/2
c	FM signal generator	Output : 200 mV across 50 Ω Deviation : up to 250 kHz Mod. freq. : up to 150 kHz	TF 1066B/6
d	Electronic voltmeter	Sensitivity : 10 mV r.m.s. or average reading dB calibration	TF 2603
e	Frequency meter	Frequency : 580 Hz to 1.5 MHz	TF 2401 series
f	LF oscillator	Frequency : 580 Hz to 56 kHz	TF 1101 (quantity 2)
g	Spectrum analyser	Resolution : 60 dB at 50 Hz	OA 1094 series or TF 2370
h	Oscilloscope	LF general purpose	-
i	Selective level meter	Frequency : 1.4 to 1.6 MHz	OA 2350 series
j	Crystal oscillator	Same frequency and output as item b in test 4.3.5	-
k	Sensitive voltmeter	Frequency : 50 Hz to 15 kHz Sensitivity : 1 mV f.s.d.	TF 2600
l	Multimeter	To measure resistance, 40 to 60 Ω	Salford Selectest
m	Amplitude modulator	AM depth : 80%	TF 1102 or TK 2181

IF output and frequency

(6) Connect the frequency meter and voltmeter to the IF OUT socket and check that the i.f. is approx. 200 mV (with the meter reading at the bottom of the black arc) and remains within 10% of 1.5 MHz when the modulation depth of the input signal is varied from 0 to 80%. (Keep the leads as short as possible.) If the frequency is in error see Sect. 5.4.10.

IF output impedance

(7) Adjust the RF LEVEL control to increase the voltage at the IF OUT socket to 700 mV. Connect a 10 kΩ ±2% resistor across the voltmeter input and check that the reading drops to between 310 and 400 mV.

4.3.3 FM deviation accuracy

Test equipment : items b, e, f and g.

The internal f.m. calibrator provides a standard of good long-term stability for checking and resetting the deviation reading accuracy as described in Section 2.5 (8). The calibrator accuracy is largely dependent on the frequency of its 200 kHz oscillator crystal, which is unlikely to change significantly. If the calibrator accuracy is suspected, the deviation reading should be checked by making a normal measurement on a symmetrically modulated signal of accurately known deviation set up by the Bessel Zero method described below.

(1) Connect the signal generator, externally modulated by the l.f. oscillator, to the inputs of the modulation meter and the spectrum analyser, as shown in Fig. 4.3.

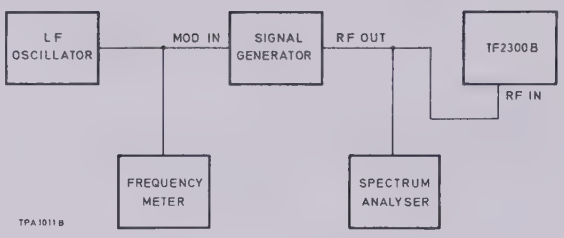


Fig. 4.3 Bessel zero measurement

(2) Adjust the oscillator frequency, checked against the frequency meter, to 26.27 kHz. Slowly increase the signal generator deviation from zero until the carrier component, viewed on the spectrum analyser, disappears for the second time. This occurs at a deviation ratio of 5.52, which means that the deviation is 145 kHz. (The FREQUENCY RESPONSE switch should be at 200 kHz.)

(3) Set up the modulation meter to measure this signal as described in Sect. 2.5, using the 150 kHz range.

TABLE 4.2

MODULATION RANGE (kHz)	*FREQUENCY RESPONSE (kHz)*	*Deviation (kHz)*	*Modulating frequency (kHz)*	*Carrier disappearance*
500	200	480	55.46	3
	200	360.7	150	1
	200	145	26.27	2
150	200	145	26.27	2
	15	48	8.696	2
50	15	48	8.696	2
	15	14.5	2.627	2
15	15	14.5	2.627	2
	15	4.8	0.8696	2
5	15	4.8	0.8696	2
1.5	15	1.4	0.5822	1

(4) If the modulation meter reading differs from 145 kHz when switched to either DEV+ or DEV-, adjust the SET CAL FM preset to give the best compromise accuracy between the two measurements. Then turn the FUNCTION switch to SET CAL and, without disturbing the SET CAL FM preset, bring the meter reading to the SET mark by adjusting the internal f.m. preset, A0R3 - see Fig. 4.1. If this has insufficient range select a new value for resistor A0R19.

(5) This check can also be made at other deviations as shown in Table 4.2.

(6) If the deviation errors show a general trend in one direction the presets A0R3, A0R4, A0R2 and A14RV1 should be adjusted to give the best compromise on their respective ranges. As A0R3 affects all ranges it should be adjusted first.

Preset	Adjust for best compromise on deviation range (kHz)
A0R3	5, 15, 50
A0R4	500
A0R2	150
A14RV1	1.5

(A0R3 will be usually found to give the best compromise by adjusting on the 5 kHz deviation range.)

4.3.4 AM depth accuracy

Test equipment : items a, f and i.

AM depth accuracy, unlike f.m. deviation, cannot be checked against an internal calibrating circuit. Therefore, the a.m. measurement accuracy can only be checked by making a normal measurement on a signal of accurately known modulation depth. A depth of about 50% is recommended. It is important that this signal should have a very low envelope distortion as this can cause an apparent error in depth indication.

The modulation depth can be checked by means of a selective level meter as follows :-

(1) Set the l.f. oscillator frequency to 3 kHz and use it to modulate the signal generator to a depth of nominally 50%.

(2) Set up the modulation meter for measuring this signal as described in Sect. 2.6.

(3) Connect the selective level meter to the IF OUT socket of the modulation meter, tune the level meter to the carrier frequency of 1.5 MHz and set its gain to give a 0 dB reference level.

(4) Retune the level meter to one of the 3 kHz sidebands and adjust the l.f. oscillator output to give a level meter reading of 12 dB below the reference level. If the sideband levels are different, adjust for a mean reading of 12 dB. This corresponds to a modulation depth of 50%.

(5) If the modulation meter reading differs from 50% when switched to either PEAK or TROUGH, adjust the internal preset A9RV1 for the best compromise accuracy between the two readings.

Note : Adjustment of A9RV1 may affect the accuracy of the f.m. deviation reading; therefore, after adjusting A9RV1, reset the f.m. calibration as shown in Sect. 2.5 (8) (not by adjusting the internal preset).

(6) This check can also be made at other modulation depths, as shown in the following table, in order to optimize reading errors.

TABLE 4.3

MODULATION RANGE (%)	Modulation depth (%)	Sideband amplitude (dB)
100	90	-6.94
100	80	-7.96
100	70	-9.12
100	60	-10.46
100	50	-12.04
100	40	-14.02
30	30	-16.52
30	20	-20.00
30	10	-26.02

The higher modulation depths are not recommended unless an unusually low envelope distortion can be achieved.

4.3.5 FM noise

Test equipment : items b, h, j and k.

This is measured by comparing the output of the modulation meter when 5 kHz deviation is applied with the output when deviation is zero. To ensure that the latter output is due to the modulation meter alone it is important that the source should be exceptionally free from spurious noise deviation.

(1) Apply an f.m. input with 5 kHz deviation from the signal generator. Connect the oscilloscope and voltmeter to the OUTPUT socket as shown in Fig. 4.4.

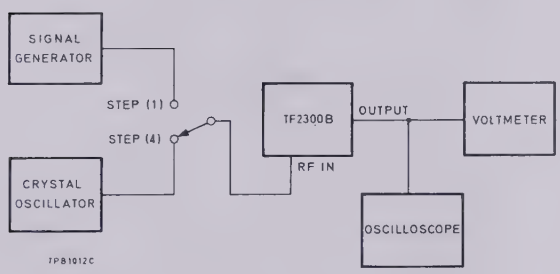


Fig. 4.4 FM noise measurement

(2) Set the modulation meter for deviation measurement as in Sect. 2.5. Switch the MODULATION RANGE switch to 5 kHz and the FREQUENCY RESPONSE switch to NOISE.

(3) Note the reading on the voltmeter - this should be about 0 dBm if the modulation meter is terminated in 600 Ω.

(4) Replace the signal generator with the external crystal oscillator set to the same carrier frequency. Increase the voltmeter sensitivity to give a suitable reading and adjust the RF LEVEL control for a minimum reading.

Note the reading on the voltmeter. The difference between this reading and the reading obtained in (3) should be 50 dB or 40 dB depending on the carrier frequency.

(5) Check that the oscilloscope trace is free from hum, external field and noise. If not, check the power supply ripple - see Sect. 5.4.3.

4.3.6 FM distortion

Test equipment : items b, c, 2f and i.

Because no signal generator is available having f.m. harmonic distortion low enough, the harmonic distortion of the modulation meter cannot be measured directly. It is therefore necessary to measure the intermodulation distortion and then to calculate the equivalent harmonic distortion.

(1) Set up the equipment as shown in Fig. 4.5. Adjust c to give a c.w. output of 200 mV at a frequency of 200 MHz. Adjust b to give a c.w. output of 50 mV at a frequency of 201.5 MHz, i.e. set to give an i.f. of 1.5 MHz.

(2) On the modulation meter, set the FUNCTION switch to TUNE and the OSCILLATOR switch to EXT. Adjust the frequency of c for a maximum reading on the meter and adjust the RF LEVEL control for a reading within the black arc.

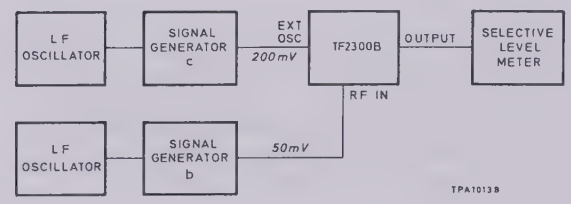


Fig. 4.5 FM distortion measurement

(3) Switch to FM SET FREQ and adjust c frequency to bring the meter reading to the SET mark.

(4) Switch to DEV+ and turn the FREQUENCY RESPONSE switch to 15 kHz and the MODULATION RANGE switch to 150 kHz.

(5) Apply external modulation to the two signal generators as shown in the following table, setting up each deviation with the other generator set to c.w.

Table 4.4

Signal generator	*Modulation frequency*	*Deviation*
c	16 kHz (f1)	37.5 kHz (d1)
b	14 kHz (f2)	37.5 kHz (d2)

(6) Switch off b and set up the level meter to give a reference level of -6 dB at f1. Switch on b again.

(7) Measure the levels of the following components :-

2nd order : (f1 -f2) : 2 kHz

3rd order : (2f2 -f1) : 12 kHz

Express the levels in dB relative to 0 dB. Add +6 dB to the 2nd order reading and +9 dB to the 3rd order reading. The r.m.s. sum of the two levels (see below for method of calculation) is equivalent to the harmonic distortion. It should be lower than -54 dB (0.2%).

(8) Repeat the test at two other settings as follows :-

(a) FREQUENCY RESPONSE switch : 200 kHz, f1 : 26 kHz, f2 : 24 kHz, d1 : 150 kHz, d2 : 150 kHz. Total deviation : 300 kHz, f1 -f2 : 2 kHz, 2f2 -f1 : 22 kHz. The distortion should be lower than -50 dB (0.3%).

(b) FREQUENCY RESPONSE switch : 200 kHz, f1 : 150 kHz, f2 : 140 kHz, d1 : 250 kHz, d2 : 250 kHz. Total deviation : 500 kHz, f1 -f2 : 10 kHz, 2f2 -f1 : 130 kHz. The distortion should be lower than -32 dB (2.5%).

Summation of dB levels

The r.m.s. sum of two dB levels can be obtained by increasing the level of the larger one by an increment between 0 and 3 dB; the value of increment depends on the difference between the two levels as shown by the graph. For example, if the two levels are -40 dB and -46 dB, giving a difference of 6 dB, the increment is 1 dB; the sum of the two levels is therefore -40 +1 dB = -39 dB.

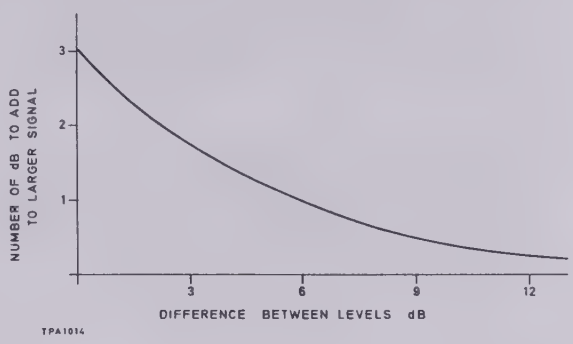


Fig. 4.6 Summation of dB levels

4.3.7 AM rejection

Test equipment : items a, f and m.

(1) Set up the equipment as shown in Fig. 4.7. Adjust the signal generator to give a c.w. output of 100 mV at any convenient frequency.

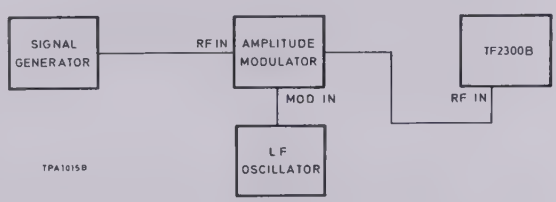


Fig. 4.7 AM rejection measurement

Adjust the l.f. oscillator frequency to 1 kHz at a level which gives 80% modulation on the meter.

(2) Set the FUNCTION switch to TUNE and the TUNE FREQUENCY controls to give a maximum meter reading. Then adjust the RF LEVEL control for a reading within the black arc.

(3) Switch to FM SET FREQ and adjust the TUNE FREQUENCY controls to bring the meter reading to the SET mark.

(4) Switch to TUNE and adjust the RF LEVEL control to give a reading just below full-scale on the black arc.

(5) Turn the MODULATION RANGE switch to 5 kHz and the FREQUENCY RESPONSE switch to 15 kHz.

(6) Switch to DEV+ and DEV- in turn and check that the residual reading on the meter is less than 500 Hz. It is typically about 150 Hz.

4.4 CLEANING AND LUBRICATING

Rotary switch contacts

These should be cleaned once or twice a year, depending on usage, with benzine or white spirit (not carbon tetrachloride). After cleaning wipe the contacts with a suitable lubricant such as a 1% solution of petroleum jelly in white spirit.

Oscillator unit

Excessive lubrication must be avoided but the moving parts should be cleaned and lubricated once or twice a year with light machine oil.

Chapter 5

Repair

5.1 INTRODUCTION

This chapter contains information for the localization and repair of faults. Performance limits quoted are for guidance only and should not be taken as guaranteed performance specifications unless they are also quoted in the Data Summary section.

CAUTION. See Maintenance, Sect. 4.1, for precautions in handling semiconductors and for advice on screw fasteners.

In the case of any difficulty, please write to or phone the Marconi Instruments Service Division (see address on back cover) or nearest representative, quoting the type and serial number on the data plate at the rear of the instrument. If the instrument is being returned for repair, please indicate clearly the nature of the fault or the work you require to be done.

5.2 FAULT LOCATION

General procedure

Methodical fault location can be performed at the following three levels :

(i) Front panel functional checks for general localization of a fault - see Sect. 5.2.2.

(ii) Internal checks for more detailed localization - see Sect. 5.2.3.

(iii) Systematic calibration, which can be used to locate a fault for which methods (i) and (ii) are inadequate - see Sect. 5.4.

5.2.1 Test equipment required

See Table 5.1.

5.2.2 Front panel checks

As a first step in fault finding, the three following tests will help you to verify nearly all the circuits of the modulation meter and to localize the fault to certain areas. These tests can be performed without removing the cover. Failure of all three tests may indicate a faulty power supply, in which case first check the fuse on the rear panel.

(1) Turn the FUNCTION switch to SET CAL. If the meter reads SET, the calibrator (A12) and the discriminator, 1st and 2nd l.f. amplifier, peak reading voltmeter and associated circuits (A5 to A10) are working. If there is no meter indication, but the 2 kHz calibrator square wave can be seen with an oscilloscope at the OUTPUT socket, then the peak reading voltmeter circuit, (A10), is faulty.

TABLE 5.1

Item	*Type*	*Minimum specification*	*Recommended model*
a	Signal generator	Frequency: 1.5 MHz and between 4 and 1000 MHz. Output: c.w., up to 100 mV.	TF 144, TF 995, TF 1066 or TF 2002 series.
b	Multimeter	20 V d.c. at 20 kΩ/V. 250 V a.c.	Salford Selectest
c	Measuring oscilloscope	Bandwidth: 5 MHz. Sensitivity: 20 mV/cm.	-

(2) Turn the FUNCTION switch to TUNE OSCILLATOR AND ADJUST LEVEL. Connect a signal to the RF IN socket and check that, by adjusting the TUNE FREQUENCY and RF LEVEL controls, a meter deflection in the black arc can be obtained. If so, the local oscillator, mixer and i.f. amplifier (A1 to A3) and most of the a.m. detector (A11) are working. If not, but the meter deflects when the input frequency is changed to the i.f. of 1.5 MHz, then the local oscillator or mixer are suspect. A fault in the local oscillator can be confirmed if the first paragraph of test 2 gives a positive result when using an external local oscillator.

(3) Turn the FUNCTION switch to FM SET FREQ. or AM SET FREQ. (after setting up the meter deflection as in step 2 above). Check that the meter deflects to the SET mark when the TUNE FREQUENCY control is slightly readjusted. If so, the limiter circuit (A4) is working.

Input attenuator

This can be checked by feeding a 1.5 MHz signal into the EXT OSCILLATOR socket when the sensitivity should be approximately 20 mV input for a meter reading on the bottom of the black arc when the FUNCTION switch is set to TUNE. If a 5 mV signal is now applied to the RF INPUT socket, a meter reading should be produced again on the black arc. If there a deflection only when the 20 mV signal is applied to the EXT OSCILLATOR socket, the attenuator or part of the mixer is faulty. It is more likely to be the attenuator.

5.2.3 Internal checks

Having roughly localized the fault by the front-panel tests it may be more accurately located by signal tracing tests, using the inter-unit wiring diagram as a guide.

(1) First check the power supply unit output voltages at C17 (+16.5 V), C21 (-18 V) and C20 (-12 V) - see Fig. 4.2 for location. If these are incorrect, reset as described in Sect. 5.4.3.

(2) If trouble is suspected between the calibrator unit and the meter, turn the FUNCTION switch to SET CAL and check the calibrator waveforms from the calibrator unit output to the meter. These should be as shown in Sect. 5.3, although the frequency of the square wave modulation is not critical and may differ from the nominal 2 kHz value illustrated.

(3) Having identified a faulty board, use the static voltage information on the circuit diagrams as a guide to locating the source of the trouble.

5.3 WAVEFORMS

The oscillograms illustrated in Fig. 5.1 show the significant waveforms that occur between the output of the calibrator unit (A12) and the OUTPUT socket. The measuring points are indicated on the inter-unit wiring diagram, Fig. 7.1, and the circuit diagrams.

Measurement should be made with an oscilloscope of at least 5 MHz bandwidth and 20 mV/cm sensitivity. Contact with the printed board edge connectors may be made from below the chassis but, if more convenient, the Extension Board TM 7926 may be used to allow access from above the chassis.

5.4 REALIGNMENT

5.4.1 Introduction

This is a complete realignment procedure with the steps arranged in a logical order. If the full procedure is not required, for example following a component replacement, individual steps may be performed providing they do not interact with other adjustments. Although the likelihood of such interaction is pointed out wherever possible, it is recommended that you always consider the effects of any readjustment by reference to the circuit diagrams.

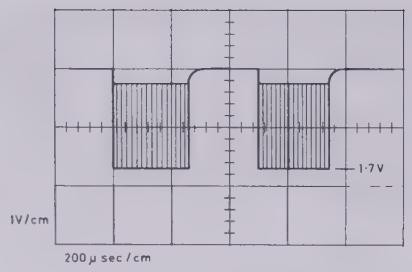
5.4.2 Test equipment required - see Table 5.2.

5.4.3 Power supply (A13)

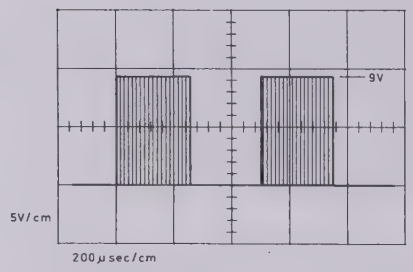
Test equipment : items a, b, c and d.

(1) Measure the output of the regulated supplies at C17, C21 and C20 - see Fig. 4.2. If the voltages are not within ±1% of nominal, adjust R17 for +16.5 V, R3 for -18 V and R11 for -12 V.

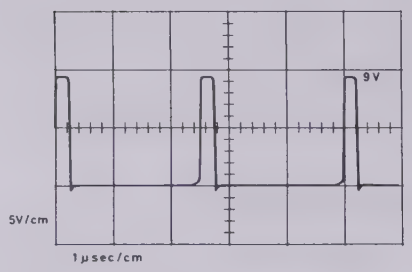
1



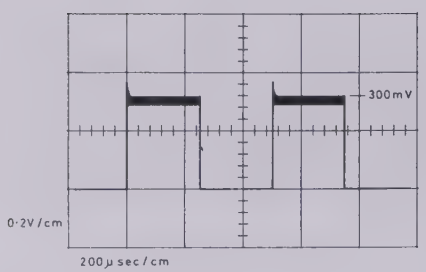
2a



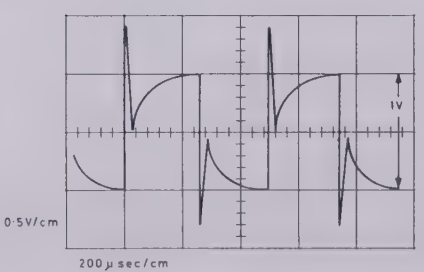
2b



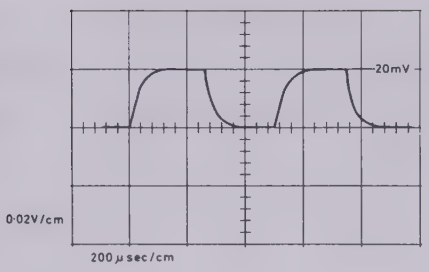
3



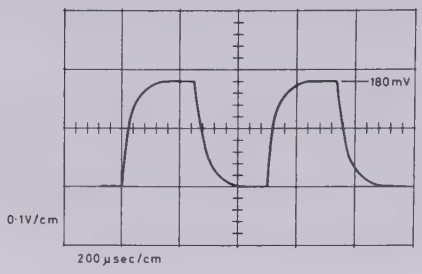
4



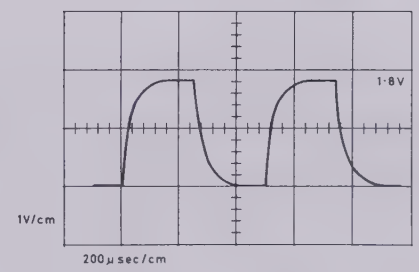
5



6



7



8

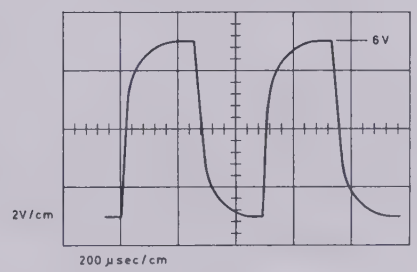


Fig. 5.1 Oscillograms

TABLE 5.2

Item	Type	Minimum specification	Recommended model
a	Multimeter	Range: 0 - 20 V d.c. 0 - 270 V a.c.	Salford Selectest
b	Variable mains transformer	Range: 190 - 260 or 90 - 160 V a.c.	Variac
c	Wave analyser	Range: 50 - 200 Hz. Sensitivity: 50 μV.	TF 2330A
d	Differential voltmeter	Discrimination: 1 mV in 18 V.	TF 2606
e	Frequency meter	Range: 5 - 150 MHz.	TF 2424A
f	Sweep generator	4 - 27 MHz.	TF 2361 with TM 9692
g	Sweep generator	27 - 255 MHz.	TF 2361 with TM 9693
h	Sweep generator	255 - 650 MHz.	TF 2361 with TM 9694
i	Sweep generator	650 - 1200 MHz.	Sanders 6700 with 6722
j	RF millivoltmeter	Range: 4 - 1200 MHz.	TF 2603
k	T connector	-	TM 7948
l	Oscilloscope	Sensitivity: 10 mV/cm.	-
m	Signal source	Range: 100 Hz - 23 kHz.	TF 2001
n	Sensitive voltmeter	Range: 100 Hz - 23 kHz.	TF 2600
o	Crystal oscillator	Frequency: 1.5 MHz.	-
p	RMS voltmeter	Frequency: 30 Hz - 150 kHz. Sensitivity: 1 mV full-scale.	-

(2) Connect the wave analyser (battery operated) to the +16.5 V line and check that the 50 Hz, 100 Hz and 150 Hz ripple components are each less than 10 μV. Check that the same components on the -18 V and the -12 V lines are each less than 10 μV.

(3) Replace the wave analyser with the differential voltmeter. Check that the +16.5 V line voltage does not change by more than ±7 mV when the a.c. supply is varied from 190 to 260 V, (or 95 to 130 V). The change on the -18 V line should be not greater than ±20 mV and on the -12 V line should be not greater than ±2 mV.

5.4.4 Local oscillator (A2, A2a and A2b)

Test equipment : item e.

(1) Connect the frequency meter to the oscillator output socket SKJ.

(2) Set the FREQUENCY RANGE switch to range 1 and set the coarse TUNE FREQUENCY control fully counter-clockwise. Check that the pointer lines up with the datum line to the left of the scale. If necessary, adjust the spindle coupling of the TUNE FREQUENCY control.

(3) Set the FREQUENCY RANGE switch to each range in turn and use the coarse TUNE FREQUENCY control to cover each range. The reading on the counter should be as follows :-

Ranges 1 and 3	5.5 to 9.5 MHz
Ranges 2 and 4	9.5 to 16.5 MHz
Ranges 5 and 7	49.5 to 85.5 MHz
Range 6	85.5 to 148.5 MHz
Range 8	85.5 to 142.5 MHz
Range 9	85.5 to 130.3 MHz
Range 10	93.07 to 148.5 MHz
Range 11	129.94 to 150.19 MHz

Check that the dial calibration is within ±3%.

(4) If the calibration accuracy is outside limits, adjust the preset resistors on the oscillator control board as follows :-

Ranges	Top of range	Bottom of range
1 and 3	R1	R2
2 and 4	R3	R4
5 and 7	R5	R6
6	R7	R8
8	R9	R10
9	R11	R12
10	R13	R14
11	R15	R16

After adjusting one end of a range, recheck the other end and readjust as necessary.

(5) If the preset resistors provide insufficient adjustment, realign the oscillator as described below.

(6) To gain access to the coils, slacken the hexagon-head bolts which hold the oscillator screening box to its mounting bracket, and slide the screening box upwards so that it comes free when the bolts disengage from the keyhole slots in the mounting bracket. There are two further keyhole slots. Insert the lower two bolts in these to hold the screening box in a convenient position.

(7) Set the fine TUNE FREQUENCY control to mid-position and set the preset resistors on the oscillator control board to minimum. After adjusting the preset resistor for one end of a range, recheck the other end and readjust the other preset resistor as necessary.

(8) Set the FREQUENCY RANGE switch to range 1 and set the coarse TUNE FREQUENCY control fully counter-clockwise. Check that the pointer is at the datum line. If necessary, adjust the control coupling. Set the coarse TUNE FREQUENCY control fully clockwise. Adjust L1 to give 9.8 MHz or the nearest frequency obtainable. Set the pointer to the 8 MHz marker and adjust R1 to give 9.5 MHz. Set the pointer to the 4 MHz marker and adjust R2 to give 5.5 MHz.

(9) Set the FREQUENCY RANGE switch to range 2 and set the coarse TUNE FREQUENCY control fully clockwise. Adjust L2 to give 17.0 MHz or the nearest frequency obtainable. Set the pointer to the 15 MHz marker and adjust R3 to give 16.5 MHz. Set the pointer to the 8 MHz marker and adjust R4 to give 9.5 MHz.

(10) Set the FREQUENCY RANGE switch to range 3. Set the pointer to the 27 MHz marker. The counter should read 9.5 MHz. Set the pointer to the 15 MHz marker and then the counter should read 5.5 MHz.

(11) Set the FREQUENCY RANGE switch to range 4. Set the pointer to the 48 MHz marker. The counter should read 16.5 MHz. Set the pointer to the 27 MHz marker and then the counter should read 9.5 MHz.

(12) Set the FREQUENCY RANGE switch to range 5 and set the coarse TUNE FREQUENCY control fully clockwise. Adjust L3 to give 88.8 MHz or the nearest frequency obtainable. There are two possible positions - use the inner one. Set the pointer to the 84 MHz marker and adjust R5 to give 85.5 MHz. Set the pointer to the 48 MHz marker and adjust R6 to give 49.5 MHz.

(13) Set the FREQUENCY RANGE switch to range 6 and set the coarse TUNE FREQUENCY control fully clockwise. Adjust L4 to give 153.0 MHz or

the nearest frequency obtainable. Set the pointer to the 147 MHz marker and adjust R7 to give 148.5 MHz. Set the pointer to the 84 MHz marker and adjust R8 to give 85.5 MHz.

(14) Set the FREQUENCY RANGE switch to range 7. Set the pointer to the 255 MHz marker. The counter should read 85.5 MHz. Set the pointer to the 147 MHz marker and then the counter should read 49.5 MHz.

(15) Set the FREQUENCY RANGE switch to range 8. Set the pointer to the 426 MHz marker and adjust R9 to give 142.5 MHz. Set the pointer to the 255 MHz marker and adjust R10 to give 85.5 MHz.

(16) Set the FREQUENCY RANGE switch to range 9. Set the pointer to the 650 MHz marker and adjust R11 to give 130.3 MHz. Set the pointer to the 426 MHz marker and adjust R12 to give 85.5 MHz.

(17) Set the FREQUENCY RANGE switch to range 10. Set the pointer to the 1038 MHz marker and adjust R13 to give 148.5 MHz. Set the pointer to the 650 MHz marker and adjust R14 to give 93.07 MHz.

(18) Set the FREQUENCY RANGE switch to range 11. Set the pointer to the 1200 MHz marker and adjust R15 to give 150.19 MHz. Set the pointer to the 1038 MHz marker and adjust R16 to give 129.94 MHz.

5.4.5 Minimum sensitivity

Test equipment : items f, g, h, i, j, k and l.

In the first part of this test, a sweep generator is used to sweep over each range with the i.f. output displayed on an oscilloscope. The i.f. response is displayed 1.5 MHz above (and also 1.5 MHz below) the frequency to which the TUNE FREQUENCY controls are set (and also harmonics of that frequency). The height of the display depends on the sensitivity of the modulation meter.

When the frequency of minimum sensitivity has thus been determined, the output from the generator is measured by means of an r.f. millivoltmeter.

(1) Insert the T connector in the RF IN socket and connect the appropriate sweep generator and the r.f. millivoltmeter to it. Connect the oscilloscope to the IF OUT socket. Also connect the X drive from the generator to the horizontal input of the oscilloscope. Set the RF LEVEL control fully clockwise.

(2) Set the sweep generator to sweep the range (plus approximately 2 MHz) and tune the coarse TUNE FREQUENCY control over the range. Note the frequency at which the display height is minimum and reset the coarse TUNE FREQUENCY control to this frequency.

(3) Set the sweep generator to manual sweep and to the same frequency to give a peak reading on the meter.

(4) Set the FUNCTION switch to SET FREQ (AM or FM) and slightly readjust the sweep generator so that the meter reading is at the SET line.

(5) Set the FUNCTION switch to TUNE OSCILLATOR and adjust the output level of the sweep generator so that the meter reading is at the lower end of the black arc.

(6) Set the OSCILLATOR switch to EXT (to switch off the internal oscillator) and note the reading on the r.f. millivoltmeter. The reading should be as follows :-

Range	Minimum sensitivity
4 to 8 MHz	Less than 12 mV
8 to 15 MHz	
15 to 27 MHz	
27 to 48 MHz	
48 to 84 MHz	
84 to 147 MHz	
147 to 255 MHz	
255 to 426 MHz	
426 to 650 MHz	Less than 35 mV
650 to 1038 MHz	
1038 to 1200 MHz	Less than 100 mV

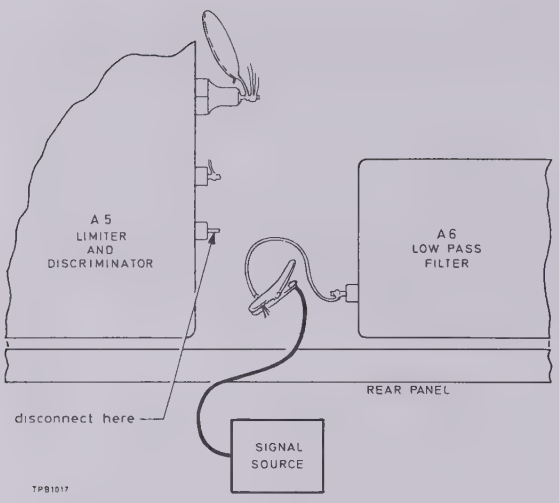


Fig. 5.2 Location of discriminator output lead

5.4.6 De-emphasis

Test equipment : items m and n.

(1) With the modulation meter switched off, disconnect the yellow lead from the discriminator unit output (A5, pin 4) and connect the lead to the output of the signal source.

(2) Connect the voltmeter to the OUTPUT socket.

(3) Turn the DE-EMPHASIS switch to 75 μs, the FUNCTION switch to DEV+ and the FREQUENCY RESPONSE switch to 200 kHz.

(4) Set the signal source frequency to 100 Hz and adjust its output level to give a suitable reference deflection on the output voltmeter.

(5) Vary the signal source frequency, keeping the output level constant, and check that the response relative to the 100 Hz reference is within ±1 dB of :

-3 dB at 2.1 kHz,
-16.9 dB at 15 kHz.

(6) Repeat step (5) with the DE-EMPHASIS switch set to 50 μs and check that the response is within ±1 dB of :

-3 dB at 3.15 kHz,
-16.9 dB at 22.5 kHz.

(7) Repeat step (5) with the DE-EMPHASIS switch set to 750 μs and check that the response is as follows :-

Within ±1 dB of -3 dB at 210 Hz,
within ±2 dB of -16.9 dB at 1.5 kHz.

5.4.7 Range attenuator

Test equipment : items m and n.

(1) Connect the signal source as in step (1) of Sect. 5.4.6.

(2) Connect the voltmeter to monitor the signal source output.

(3) Turn the MODULATION RANGE switch to 5 kHz and the DE-EMPHASIS switch to OFF.

(4) Set the signal source frequency to 1 kHz and adjust its output to give full-scale deflection on the meter.

(5) Turn the MODULATION RANGE switch to 15 kHz. Increase the signal source output by 10 dB and check that the meter reads within ±1% of full-scale.

(6) Repeat step (5) for the 50, 150 and 500 kHz deviation ranges. If there is an error on the 150 and 500 kHz ranges, it may be necessary to adjust A0R2 or A0R4 - see Sect. 4.3.3.

(7) Switch off, remove the test equipment and reconnect the yellow lead to the discriminator output.

5.4.8 AM and l.f. response

Test equipment : items m and n.

(1) On the a.m. detector unit (A11), disconnect the link from pins 17 and 18. Then connect the signal source between pins 18 and 10 (earth).

(2) Turn the MODULATION RANGE switch to 100% and the FUNCTION switch to AM PEAK.

(3) Connect one voltmeter across the OUTPUT socket and another to monitor the signal source output.

(4) Set the signal source frequency to 10 kHz and its output to give a reading of 100% on the modulation meter. Note the reference level on the output voltmeter.

(5) Vary the signal source frequency, keeping the level constant, between 30 Hz and 50 kHz and note that the reading on the output voltmeter is flat to within ±0.25 dB of the reference level.

(6) Switch off, remove the test equipment and replace the link between A11 pins 17 and 18.

5.4.9 Discriminator trigger

Test equipment : item a.

(1) With the modulation meter switched off, disconnect the lead from pin 2 on the discriminator unit (A5) and connect the multimeter to the collector of A5VT2 (or VT3).

(2) Switch on and adjust A5RV1 to a point where the circuit is at change of state, i.e. multimeter either reads 0 V or 15 V. When the potentiometer is adjusted the voltage will jump either to 15 V or 0 V from the original reading. Set to a position just before it jumps.

(3) Transfer the meter to pin 7 (i.e. test point adjacent to RV1). Note the voltage and decrease it by 0.5 V by rotating RV1 counter-clockwise. Check that the output waveform at the output terminals of the instrument is free from spurious pulses. Switch off and reconnect pin 2.

5.4.10 Set i.f.

Test equipment : item o.

(1) Connect the crystal oscillator to the RF IN socket.

(2) Turn the OSCILLATOR switch to EXT and the FUNCTION switch to TUNE.

(3) Set the RF LEVEL control for a meter reading at the top end of the black arc.

(4) Turn the FUNCTION switch to FM SET FREQ and adjust A4L1 through the hole in the limiter/discriminator cover (see Fig. 4.2) to bring the meter reading to the SET mark.

5.4.11 LF and discriminator noise

Test equipment : items l, o and p.

(1) Connect the r.m.s. voltmeter and the oscilloscope to the OUTPUT socket.

(2) Turn the OSCILLATOR switch to EXT.

(3) Connect the 1.5 MHz crystal oscillator to the RF IN socket and turn the FREQUENCY RESPONSE switch to NOISE.

(4) Turn the FUNCTION switch to SET FREQ FM and check that the meter deflects to the SET mark.

(5) Turn the FUNCTION switch to TUNE and adjust the LEVEL control to bring the meter reading to the top end of the black arc.

(6) Turn the FUNCTION switch to SET CAL and adjust the r.m.s. voltmeter range switch to give a convenient reference level. Note this reference level.

(7) Turn the FUNCTION switch to DEV+ and the MODULATION RANGE switch to 5 kHz. Increase the external voltmeter sensitivity and check that the reading is at least 55 dB below the reference level, i.e. -75 dB relative to the level of 50 kHz deviation.

(8) If not, remove the yellow lead from the discriminator output, A5 pin 4 (see Fig. 5.2) and check that the noise level drops to -68 dB. A high noise figure can be improved by selection of transistors VT3, VT4, VT5 and VT6 in the discriminator (A5).

5.5 REPLACEMENT OF SUB-ASSEMBLIES

Oscillator

To lift out the lid of the oscillator screening box and the control board, mount the box as described in Sect. 5.4.4(6), detach the lead from the control board to the feed-through capacitor on the inner side of the box and remove the four screws holding on the lid.

To withdraw the oscillator board, unsolder the seven leads from the feed-through capacitors and the socket and remove the four pillars and the three screws.

IF amplifier

To remove the lid of the screening box, remove the four screws.

To remove the complete assembly, unsolder the lead from the lead-through terminal, withdraw the two miniature plugs and remove the two screws on the rear panel and the one screw on the chassis.

To remove the board, remove the eight screws, lift up the board and unsolder the lead from the lead-through terminal and the leads from the two sockets.

Limiter and discriminator

To remove the lid of the screening box, remove the four screws.

To remove the limiter board, unsolder the five leads from the feed-through capacitors, the lead-through terminals and the discriminator board and remove the four nuts.

To remove the discriminator board, unsolder the five leads from the feed-through capacitors and the lead-through terminals and remove the four nuts

Printed circuit boards

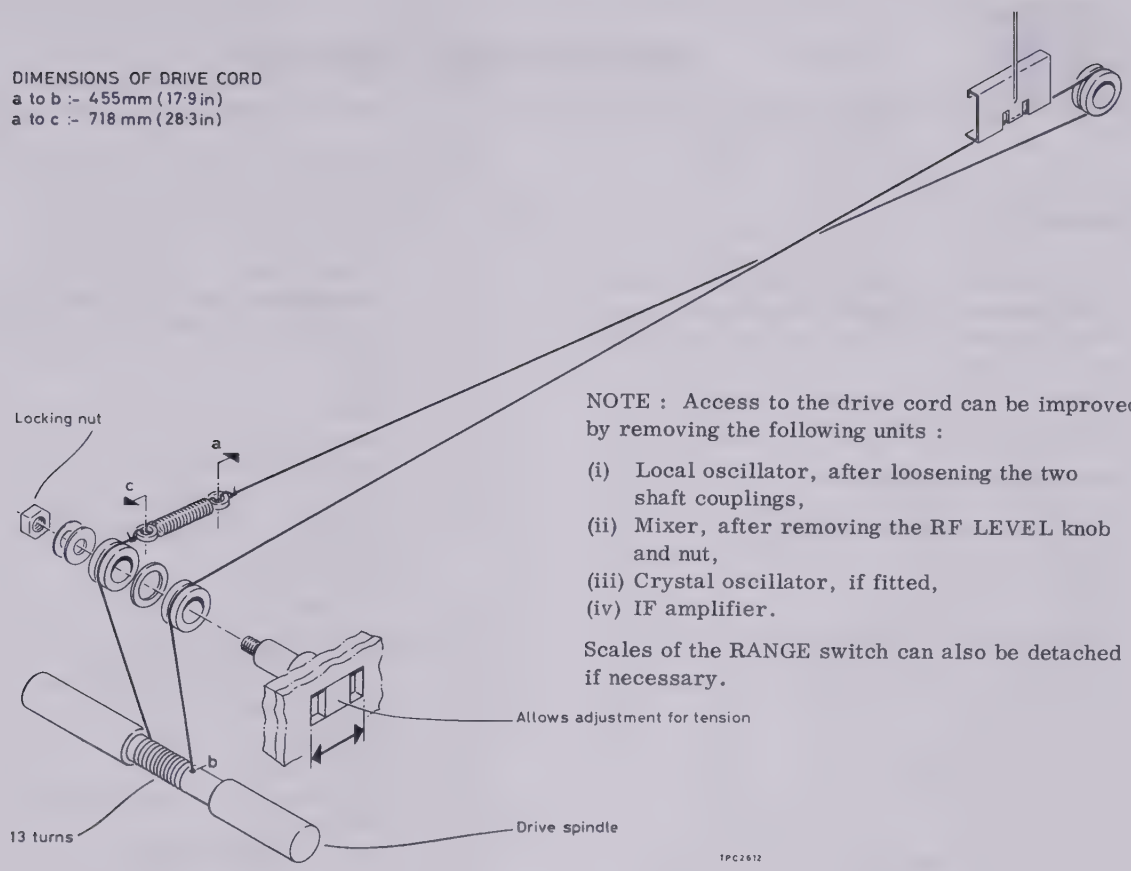
The following are plug-in circuit boards which can be removed by pressing a spring clip and pulling the board upwards :

(1) 1st l.f. amplifier (A7).
(2) 2nd l.f. amplifier (A9).
(3) Peak reading voltmeter (A10).
(4) AM detector (A11).
(5) Calibrator (A12).

An extension board, type TM 7926, is stowed on the inside of the rear panel. By means of this board, any of the above can be raised above its compartment for examination while in the operative condition.

Power supply unit

To lift out the power supply board, remove the two screws.



NOTE : Access to the drive cord can be improved by removing the following units :

(i) Local oscillator, after loosening the two shaft couplings,
(ii) Mixer, after removing the RF LEVEL knob and nut,
(iii) Crystal oscillator, if fitted,
(iv) IF amplifier.

Scales of the RANGE switch can also be detached if necessary.

Fig. 5.3 Fitting drive cord

5.6 OSCILLATOR DRIVE CORD

Details of the drive cord are shown in Fig. 5.3.

5.7 REPLACEMENT OF COMPONENTS

Fuse

The fuse is fitted in a 20 x 50 mm holder in the rear panel. It must never be changed without first switching off the mains supply, or circuit damage may result.

Transistors

Transistors that are mounted in holders may need to be selected for low noise if replaced.

Crystal

On the calibrator (Unit A12), the crystal fitted may either have pins to fit a socket or be wire-ended. The socket is always fitted, but with a wire-ended crystal, the socket contacts are removed and taped to the board beneath the crystal. Either type of crystal may be used for replacement, but if a type with pins is to replace a wire-ended type, the socket contacts must be refitted and connected to tags 13 and 14.

RF attenuator

AT1 is a sealed unit. Contact Marconi Instruments if repair appears necessary in this unit.

Chapter 6

Replaceable parts

Introduction

The modulation meter consists of a number of sub-assemblies, each of which is allocated an identity number in the sequence A0 to A15 inclusive, as follows :-

A0 - Main chassis
A1 - Mixer
A2 - Oscillator assembly
  A2a Oscillator
  A2b Oscillator controls
A3 - IF amplifier
A4 - Limiter
A5 - Discriminator
A6 - 200 kHz l.p. filter
A7 - 1st l.f. amplifier
A8 - 15 kHz l.p. filter
A9 - 2nd l.f. amplifier
A10 - Peak reading voltmeter
A11 - AM detector
A12 - Calibrator
A13 - Power supply unit assembly
A14 - Component board
A15 - Oscillator switch

The complete reference of a part consists of the sub-assembly number followed by its circuit reference, e.g., A4C5, A7R4, etc., and this should always be stated on any order, letter, etc. For convenience in the text and on circuit diagrams, the circuit reference is abbreviated by dropping the sub-assembly prefix except where there is a risk of ambiguity.

Replaceable parts are grouped in order of sub-assembly designation and itemized in alpha-numerical order of circuit references, with miscellaneous parts at the end of each list. The following abbreviations are used :-

C : capacitor
Carb : carbon
Cer : ceramic
D : semiconductor diode
Elec : electrolytic
FS : fuse
IC : integrated circuit
L : inductor
LP : lamp
M : meter
Met : metal
Min : minimum value
MR : semiconductor diode
Ox : oxide
PL : plug
Plas : plastic
R : resistor
RV : variable resistor
S : switch
SK : socket
SKT : socket
T : transformer
Tant : tantalum
TR : transistor
Var : variable or preset
VT : transistor
W : watts at 70°C
WW : wirewound
X : ferrite bead
† : value selected during test; nominal value listed
Ø : feed-through component

Ordering

When ordering replacement or spare parts, address the order to our Service Division (for address see rear cover) or nearest representative. Please specify the following information for each part required.

(1) Type and serial number of instrument (see rear data plate).
(2) Complete circuit reference (see Introduction).
(3) Description.
(4) M.I. code number.

If a part is not listed, state its function, location and description when ordering.

One or more of the parts fitted to the instrument may differ from those listed in this chapter for any of the following reasons :

(a) Components indicated by † have their value selected during test to achieve particular performance limits.

(b) Owing to supply difficulties components may be substituted by others of different type or value provided that the overall performance of the instrument is maintained.

(c) As part of a policy of continuous development, components may be changed in value or type to obtain detail improvements in performance.

Whenever there is such a difference between the component fitted and the one listed, always use a replacement the same type and value as found in the instrument.

Transistor selection

Transistors that are mounted in holders may need to be selected for low noise if replaced.

A0—Main assembly with range attenuator

When ordering, prefix circuit reference with A0

Circuit reference	*Description*	*M.I. code*
C1	Cer 0.1μF +50-25% 30V	26383-031
C2	Cer 0.1μF +50-25% 30V	26383-031
C3	Cer 0.1μF +50-25% 30V	26383-031
C4	Cer 0.1μF +50-25% 30V	26383-031
C5	Plas 0.201μF ±1.1% 125V	26518-330
C6	Plas 0.302μF ±1.1% 125V	26518-341
C7	Plas 0.047μF ±10% 250V	26582-206
C8	Cer 0.1μF +50-25% 30V	26383-031
C9	Plas 0.047μF ±10% 400V	26555-471
C10	Cer 500pF ±10% 500V	26364-301
C12	Plas 3.3μF ±5% 60V	26551-242
C13	Plas 0.04μF ±1% 125V	26516-818
C14	Plas 1.5μF ±2% 100V	26511-398
LP1	Red neon lamp 110V	23733-154
M1	Meter	44559-006
PLA	Plug, r.f. miniature	23441-014
PLB	Plug, r.f. miniature	23441-014
PLC	Plug, r.f. miniature	23441-014
R1	Var carb 3.3kΩ ±20% 2W	25645-354
R2	Var WW 500Ω ±10% 1W	25815-147
R3	Var WW 5kΩ ±10% 1W	25815-129
R4	Var WW 500Ω ±10% 1W	25815-147
R5	Var WW 5kΩ ±10% 1W	25815-130
R6	Var carb 100kΩ ±20% 2W	25645-441
R8	Met film 1.925kΩ ±0.5% ¼W	24635-008
R9	Met film 1.423kΩ ±0.5% ¼W	24635-009
R10	Met film 1.925kΩ ±0.5% ¼W	24635-008
R11	Met film 1.222kΩ ±0.5% ¼W	24635-006
R12	Met film 4.95kΩ ±0.5% ¼W	24635-104
R13	Met film 1.18kΩ ±0.5% ¼W	24635-010
R14	Met film 1.027kΩ ±0.5% ¼W	24635-005
R15	Met film 33.00kΩ ±1% ¼W	24637-556
R16	Met film 1.027kΩ ±0.5% ¼W	24635-005
R18	Met film 220kΩ ±2% ¼W	24773-329
R19	Met film 220kΩ ±2% ¼W	24773-329
R21	Met film 10kΩ ±2% ¼W	24773-297
R22	Met film 1.222kΩ ±0.5% ¼W	24635-006
R23	Met film 4.95kΩ ±0.5% ¼W	24635-104
R24	Met film 1.222kΩ ±0.5% ¼W	24635-006
R26	Met ox 22Ω ±2% ½W	24573-033
SA	SUPPLY switch	23462-258
SB	FUNCTION switch	44340-057
SC	MODULATION RANGE switch	44340-056
SD	DE-EMPHASIS switch	44340-059
SE	FREQUENCY RESPONSE switch	44340-060
SKK	IF OUT socket, 50Ω, BNC	23443-443
SKL	OUTPUT socket, 50Ω, BNC	23443-443

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
A1—Mixer 44990-075		
When ordering, prefix circuit reference with A1		
AT1	Attenuator assembly	44429-006
MR1	Diode TIV305	28349-001
R1	Met film 2.7kΩ ±2% ¼W	24773-283
R2	Met film 470Ω ±2% ¼W	24773-265
R3	Met film 56Ω ±2% ¼W	24773-243
R4	Met film 10kΩ ±2% ¼W	24773-297
SKC	Socket, r.f. miniature	23441-044
SKD	RF IN socket, 50Ω, BNC	23443-503
SKE	Socket, 50Ω, BNC	23443-413
A2—Oscillator 44990-080		
When ordering, prefix circuit reference with A2		
C24	Cer 0.0047μF +80-20% 500V	26373-665
C25	Cer 0.0047μF +80-20% 500V	26373-665
C26	Cer 0.0047μF +80-20% 500V	26373-665
C27	Cer 0.0047μF +80-20% 500V	26373-665
C28	Cer 0.0047μF +80-20% 500V	26373-665
C29	Cer 0.0047μF +80-20% 500V	26373-665
C30	Cer 0.1μF +50-20% 30V	26383-031
R1	Var WW 10kΩ ±5% 2W	25885-151
SA	FREQUENCY RANGE switch	44340-058
SKJ	Socket, 50Ω, BNC	23443-461
A2a—Oscillator 44827-276		
When ordering, prefix circuit reference with A2a		
C1	Plas 0.47μF ±10% 63V	26582-410
C2	Cer 0.0μF +80-20% 100V	26383-055
C3	Elec 100μF +100-20% 25V	26423-243
C4	Cer 0.01μF +80-20% 100V	26383-055
C5	Cer 0.01μF +80-20% 100V	26383-055
C6	Plas 560pF ±2% 125V	26516-423
C7	Elec 100μF +100-20% 25V	26423-243
C8	Cer 0.01μF +80-20% 100V	26383-055
C9	Cer 0.01μF +80-20% 100V	26383-055
C10	Plas 330pF ±2% 125V	26516-369
C11	Elec 100μF +100-20% 25V	26423-243
C12	Cer 0.01μF +80-20% 100V	26383-055
C13	Cer 0.01μF +80-20% 100V	26383-055
C14	Cer 560pF ±2% 125V	26516-423
C15	Elec 100μF +100-20% 25V	26423-243
C16	Cer 0.01μF +80-20% 100V	26383-055
C17	Cer 0.001μF +80-20% 500V	26383-242
C18	Cer 0.001μF +80-20% 500V	26383-242
C19	Cer 0.01μF +80-20% 100V	26383-055
C20	Elec 22μF +100-20% 25V	26415-805
C21	Cer 0.001μF +80-20% 500V	26383-242
C22	Elec 100μF +100-20% 25V	26415-813
D1 to D6	BB105	
D7 to D12	BB105	
D13 to D17	BB105	
D18 to D21	BB105	
D22	1N4148	
D23	1N4148	
D24	1N4148	
D25	1N4148	
L1	Coil assembly	44290-138
L2	Coil assembly	44290-137
L3	Coil assembly	44290-136
L4	Coil assembly	44290-135
R1	Met film 4.7kΩ ±2% ¼W	24773-289
R2	Met film 300Ω ±2% ¼W	24773-260
R3	Met film 3kΩ ±2% ¼W	24773-284
R4	Met film 10kΩ ±2% ¼W	24773-297

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
R5	Met film 300Ω ±2% ¼W	24773-260
R6	Met film 3kΩ ±2% ¼W	24773-284
R7	Met film 10kΩ ±2% ¼W	24773-297
R8	Met film 300Ω ±2% ¼W	24773-260
R9 †	Met film 3kΩ ±2% ¼W	24773-284
R10	Met film 10kΩ ±2% ¼W	24773-297
R11	Met film 300Ω ±2% ¼W	24773-260
R12	Met film 1.2kΩ ±2% ¼W	24773-275
R13	Met film 10kΩ ±2% ¼W	24773-297
R14	Met film 3.3kΩ ±2% ¼W	24773-285
R15	Met film 4.7kΩ ±2% ¼W	24773-289
R16	Met film 680Ω ±2% ¼W	24773-269
R17	Met film 2kΩ ±2% ¼W	24773-280
R18	Met film 200Ω ±2% ¼W	24773-256
R19 †	Met film 33Ω ±2% ¼W	24773-213
T1	Oscillator transformer	43541-014
TR1	BF 244B	28459-011
TR2	BF 244B	28459-011
TR3	BF 244B	28459-011
TR4	WN428	28459-025
TR5	BSX 20	28452-197

A2b—Oscillator Controls 44827-274

When ordering, prefix circuit reference with A2b

R1	Var carb 1kΩ ±20% ¼W	25611-072
R2	Var carb 2.2kΩ ±20% ¼W	25611-074
R3	Var carb 4.7kΩ ±20% ¼W	25611-076
R4	Var carb 2.2kΩ ±20% ¼W	25611-074
R5	Var carb 1kΩ ±20% ¼W	25611-072
R6	Var carb 2.2kΩ ±20% ¼W	25611-074
R7	Var carb 1kΩ ±20% ¼W	25611-072
R8	Var carb 2.2kΩ ±20% ¼W	25611-074
R9	Var carb 4.7kΩ ±20% ¼W	25611-078
R10	Var carb 2.2kΩ ±20% ¼W	25611-074
R11	Var carb 4.7kΩ ±20% ¼W	25611-078
R12	Var carb 4.7kΩ ±20% ¼W	25611-076
R13	Var carb 1kΩ ±20% ¼W	25611-072
R14	Var carb 4.7kΩ ±20% ¼W	25611-076
R15	Var carb 1kΩ ±20% ¼W	25611-072
R16	Var carb 22kΩ ±20% ¼W	25611-080
R17	Met film 10kΩ ±2% ¼W	24773-297
R18	Carb 1MΩ ±5% 1/8W	24311-945

A3—IF Amplifier TM 7132

When ordering, prefix circuit reference with A3

C1	Cer 0.1μF +50-25% 25 V	26383-031
C2	Cer 0.1μF +50-25% 25 V	26383-031
C3	Cer 0.1μF +50-25% 25 V	26383-031
C4	Cer 0.1μF +50-25% 25 V	26383-031
C5	Mica 352pF ±1% 750 V	26258-141
C6	Mica 352pF ±1% 750 V	26258-141
C7	Cer 0.1μF +50-25% 25 V	26383-031
C8	Cer 0.1μF +50-25% 25 V	26383-031
C9	Cer 0.1μF +50-25% 25 V	26383-031
C10	Cer 0.1μF +50-25% 25 V	26383-031
C11	Mica 352pF ±1% 750 V	26258-141
C12	Mica 352pF ±1% 750 V	26258-141
C13	Cer 0.1μF +50-25% 25 V	26383-031
C14	Cer 0.1μF +50-25% 25 V	26383-031
C15	Cer 0.1μF +50-25% 25 V	26383-031
C16	Cer 0.1μF +50-25% 25 V	26383-031
C18	Cer 0.1μF +50-25% 25 V	26383-031
C19	Cer Ø 0.001μF min. 350 V	26372-611
L1	55.2 μH	44257-402
L2	55.2 μH	44257-402
L3	55.2 μH	44257-402
L4	55.2 μH	44257-402
L5	55.2 μH	44257-402
L6	55.2 μH	44257-402

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
R1	Met ox 3.9kΩ ±2% ½W	24573-087
R2	Met ox 18kΩ ±2% ½W	24573-103
R3	Met ox 820Ω ±2% ½W	24573-071
R4	Met ox 200Ω ±2% ½W	24573-056
R5	Met ox 3.9kΩ ±2% ½W	24573-087
R6	Met film 39Ω ±2% ¼W	24773-239
R7	Met film 1.5kΩ ±2% ¼W	24773-277
R8	Met ox 560Ω ±2% ½W	24573-067
R9	Met ox 470Ω ±2% ½W	24573-065
R10	Met ox 2.7kΩ ±2% ½W	24573-083
R11	Met ox 11kΩ ±2% ½W	24573-098
R12	Met ox 150Ω ±2% ½W	24573-053
R13	Met ox 2.2kΩ ±2% ½W	24573-081
R14	Met film 39Ω ±2% ¼W	24773-239
R15	Met film 1.5kΩ ±2% ¼W	24773-277
R16	Met ox 560Ω ±2% ½W	24573-067
R17	Met ox 470Ω 2% ½W	24573-065
R18	Met ox 18kΩ ±2% ½W	24573-103
R19	Met ox 4.7kΩ ±2% ½W	24573-089
R20	Met ox 3.3kΩ ±2% ½W	24573-085
R21	Met ox 390Ω ±2% ½W	24573-063
R22	Met ox 1.2kΩ ±2% ½W	24573-075
R23	Met film 22Ω ±2% ¼W	24773-233
R24	Met film 680Ω ±2% ¼W	24773-269
SKTA	RF miniature	23441-044
SKTB	RF miniature	23441-044
VT1	MPS 3640	28431-766
VT2	MPS 3640	28431-766
VT3	MPS 3640	28431-766
VT4	BCY 72	28433-487
VT5	BCY 72	28433-487
VT6	BCY 72	28433-487

A4—Limiter TM 7285

When ordering, prefix circuit reference with A4

Circuit reference	Description	M.I. code
C1	Cer 0.1μF +50-25% 25 V	26383-031
C2	Cer 0.1μF +50-25% 25 V	26383-031
C3	Cer 0.1μF +50-25% 25 V	26383-031
C4	Cer 0.1μF +50-25% 25 V	26383-031
C5	Cer 0.1μF +50-25% 25 V	26383-031
C6	Cer 0.1μF +50-25% 25 V	26383-031
C7	Cer 0.1μF +50-25% 25 V	26383-031
C8	Cer 0.1μF +50-25% 25 V	26383-031
C9	Cer 0.1μF +50-25% 25 V	26383-031
C10	Cer 0.1μF +50-25% 25 V	26383-031
C11	Cer 0.1μF +50-25% 25 V	26383-031
C12	Cer 0.1μF +50-25% 25 V	26383-031
C13	Cer Ø 0.0047μF min. 350 V	26372-615
C14	Cer Ø 0.0047μF min. 350 V	26372-615
L1	Assembly TM 8073/2	44253-208
MR1	CG85H	28321-201
R1	Met film 1kΩ ±2% ¼W	24773-273
R2	Met film 330Ω ±2% ¼W	24773-261
R3	Met film 680Ω ±2% ¼W	24773-269
R4	Met film 470Ω ±2% ¼W	24773-265
R5	Met film 100Ω ±2% ¼W	24773-249
R6	Met film 680Ω ±2% ¼W	24773-269
R7	Met film 330Ω ±2% ¼W	24773-261
R8	Met film 1kΩ ±2% ¼W	24773-273
R9	Met film 1kΩ ±2% ¼W	24773-273
R10	Met film 330Ω ±2% ¼W	24773-261
R11	Met film 470Ω ±2% ¼W	24773-265
R12	Met film 100Ω ±2% ¼W	24773-249
R13	Met film 680Ω ±2% ¼W	24773-269
R14	Met film 330Ω ±2% ¼W	24773-261

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
R15	Met ox 2kΩ ±2% ½W	24573-080
R16	Met film 1kΩ ±2% ¼W	24773-273
R17	Met film 330Ω ±2% ¼W	24773-261
R18	Met ox 560Ω ±2% ½W	24573-067
R19	Met ox 470Ω ±2% ½W	24573-065
R20	Met film 100Ω ±2% ¼W	24773-249
R21	Met film 180Ω ±2% ¼W	24773-255
R22	Met film 330Ω ±2% ¼W	24773-261
R23	Met ox 2.2kΩ ±2% ½W	24573-081
R24	Met ox 2.7kΩ ±2% ½W	24573-083
RV1	Var carb 100Ω ±20% ¼W	25611-102
RV2	Var carb 100Ω ±20% ¼W	25611-102
RV3	Var carb 100Ω ±20% ¼W	25611-102
VT1	BCY72	28433-487
VT2	BCY72	28433-487
VT3	BCY72	28433-487
VT4	BCY72	28433-487
VT5	BCY72	28433-487
VT6	BCY72	28433-487
X1	Ferrite bead, FX1115	23635-833
X2	Ferrite bead, FX1115	23635-833
X3	Ferrite bead, FX1115	23635-833
X4	Ferrite bead, FX1115	23635-833
X5	Ferrite bead, FX1115	23635-833

A5—Discriminator 44827-264

When ordering, prefix circuit reference with A5

Circuit reference	Description	M.I. code
C1	Cer 0.1μF +50-25% 25 V	26383-031
C2	Cer 10pF ±0.5pF 750 V	26324-085
C3	Cer 10pF ±0.5pF 750 V	26324-085
C4	Cer 6.8pF ±0.25pF 750 V	26324-706
C5	Plas 39pF ±2pF 125 V	26516-145
C6	Elec 100μF +100-20% 25 V	26415-813
C7	Cer 0.1μF +50-25% 25 V	26383-031
C8	Cer 0.1μF +50-25% 25 V	26383-031
C9	Elec 100μF +100-20% 25 V	26415-813
C10	Cer 0.1μF +50-25% 25 V	26383-031
C11	Cer 0.1μF +50-25% 25 V	26383-031
C13	Cer Ø 0.0047μF min. 350 V	26372-615
C14	Cer Ø 0.0047μF min. 350 V	26372-615
MR1	CG85H	28321-201
MR2	CG85H	28321-201
R1	Met film 1.5kΩ ±2% ¼W	24773-277
R2	Met film 1.8kΩ ±2% ¼W	24773-279
R3	Met film 3.3kΩ ±2% ¼W	24773-285
R4	Met film 33Ω ±2% ¼W	24773-237
R5	Met ox 1kΩ ±2% ½W	24573-073
R6	Met film 100Ω ±2% ¼W	24773-249
R7	Met film 470Ω ±2% ¼W	24773-265
R8	Met film 10kΩ ±2% ¼W	24773-297
R9	Met film 22kΩ ±2% ¼W	24773-305
R10	Met ox 5.6kΩ ±2% ½W	24573-091
R11	Met film 10kΩ ±2% ¼W	24773-297
R12	Met ox 1kΩ ±2% ½W	24573-073
R13	Met ox 200Ω ±2% ½W	24573-056
R14	Met ox 1kΩ ±2% ½W	24573-073
R15	Met ox 8.2kΩ ±2% ½W	24573-095
R16	Met film 33Ω ±2% ¼W	24773-237
R17	Met film 470Ω ±2% ¼W	24773-265
R18	Met film 470Ω ±2% ¼W	24773-265
RV1	Var carb 4.7kΩ ±20% ¼W	25611-122
VT1	BSX20	28452-197
VT2	BSX20	28452-197
VT3	BSX20	28452-197
VT4	BSX20	28452-197

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
VT5	BSY27	28452-843
VT6	BC109	28452-777
VT7	BC109	28452-777
X1	Ferrite bead, FX1115	23635-833
X2	Ferrite bead, FX1115	23635-833
X3	Ferrite bead, FX1115	23635-833

A6—200 kHz Low-pass Filter TM 7700

When ordering, prefix circuit reference with A6

C1	Mica 720 pF ±1% 350 V	26258-150
C2	Mica 0.00144 μF ±1% 350 V	26258-185
C3	Mica 720 pF ±1% 350 V	26258-150
L1	Assembly TM 7842	44266-821
L2	Assembly TM 7842	44266-821
R1	Met film 1 kΩ ±1% ¼ W	24637-101

A7—1st LF Amplifier 44827-265

When ordering, prefix circuit reference with A7

C1	Elec 470μF +100-20% 25 V	26415-822
C2	Elec 100μF +100-20% 25 V	26415-813
C3	Cer 15pF ±5% 750 V	26324-795
C4	Elec 100μF +100-20% 25 V	26415-813
C5	Elec 100μF +100-20% 25 V	26415-813
C6	Elec 100μF +100-20% 25 V	26415-813
C7	Elec 470μF +100-20% 25 V	26415-822
R1	Met film 100Ω ±2% ¼W	24773-249
R2	Met film 1kΩ ±1% ¼W	24637-101
R3	Met film 5.6kΩ ±2% ¼W	24773-291
R4	Met film 2.2kΩ ±2% ¼W	24773-281
R5	Met film 4.7kΩ ±2% ¼W	24773-289
R6	Met film 5.6kΩ ±2% ¼W	24773-291
R7	Met ox 3.3kΩ ±2% ½W	24573-085
R8	Met ox 20kΩ ±2% ½W	24573-104
R9	Met film 2.2kΩ ±2% ¼W	24773-281
R10	Met film 56Ω ±2% ¼W	24773-243
R11	Met film 82Ω ±2% ¼W	24773-247
R12	Met film 22kΩ ±2% ¼W	24773-305
R13	Met film 1kΩ ±2% ¼W	24773-273
R14	Met film 1kΩ ±1% ¼W	24637-101
VT1	BCY71	28435-235
VT2	BCY71	28435-235
VT3	2N1304	28443-528
VT4	2N1304	28443-528

A8—15 kHz Low-pass Filter TM 7702

When ordering, prefix circuit reference with A8

C1	Plas 0.0067 μF ±1% 125 V	26516-683
C2	Plas 0.0067 μF ±1% 125 V	26516-683
L1	Assembly TM 7842/1	44271-409

A9—2nd LF Amplifier TM 8806

When ordering, prefix circuit reference with A9

C1	Elec 470μF +100-20% 25 V	26415-822
C2	Cer 0.1μF +50-25% 30 V	26383-031
C3	Cer 15pF ±5% 750 V	26324-795
C4	Elec 100μF +100-20% 25 V	26415-813
C5	Elec 100μF +100-20% 25 V	26415-813
C6	Elec 100μF +100-20% 25 V	26415-813
C7	Elec 470μF +100-20% 25 V	26415-822
C8	Cer 15pF ±5% 750 V	26324-795
C9	Elec 100μF +100-20% 25 V	26415-813
C10	Elec 100μF +100-20% 25 V	26415-813

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
C11	Elec 470μF +100-20% 25 V	26415-822
C12	Elec 100μF +100-20% 25 V	26415-813
R1	Met film 47Ω ±2% ¼W	24773-241
R2	Met film 1kΩ ±1% ¼W	24637-101
R3	Met film 5.6kΩ ±2% ¼W	24773-291
R4	Met film 2.2kΩ ±2% ¼W	24773-281
R5	Met film 4.7kΩ ±2% ¼W	24773-289
R6	Met film 5.6kΩ ±2% ¼W	24773-291
R7	Met ox 20kΩ ±2% ½W	24573-104
R8	Met ox 10kΩ ±2% ½W	24573-097
R9	Met film 2.2kΩ ±2% ¼W	24773-281
R10	Met film 500Ω ±1% ¼W	24636-808
R11	Met film 500Ω ±1% ¼W	24636-808
R12	Met film 5.6kΩ ±2% ¼W	24773-291
R13	Met film 2.2kΩ ±2% ¼W	24773-281
R14	Met film 4.7kΩ ±2% ¼W	24773-289
R15	Met film 5.6kΩ ±2% ¼W	24773-291
R16	Met ox 20kΩ ±2% ½W	24573-104
R17	Met film 2.2kΩ ±2% ¼W	24773-281
R18	Met film 56Ω ±2% ¼W	24773-243
R19	Met film 82Ω ±2% ¼W	24773-247
R20	Met film 22kΩ ±2% ¼W	24773-305
R21	Met film 1kΩ ±2% ¼W	24773-273
R22	Met film 600Ω ±1% ¼W	24636-802
RV1	Var WW 22kΩ ±10% 1W	25811-554
VT1	BCY 72	28433-487
VT2	BCY 72	28433-487
VT3	BCY 72	28433-487
VT4	BCY 72	28433-487
VT5	2N1304	28443-528
VT6	2N1304	28443-528

A10—Peak Reading Voltmeter TM 8805

When ordering, prefix circuit reference with A10

Circuit reference	Description	M.I. code
C1	Elec 100μF +100-20% 25 V	26415-813
C2	Cer 0.1μF +50-25% 30 V	26383-031
C3	Elec 470μF +100-20% 25 V	26415-822
C4	Elec 100μF +100-20% 25 V	26415-813
C5	Elec 100μF +100-20% 25 V	26415-813
C6	Elec 100μF +100-20% 25 V	26415-813
C7	Elec 100μF +100-20% 25 V	26415-813
C8	Elec 15μF ±20% 15 V	26485-278
C9	Elec 100μF +100-20% 25 V	26415-813
C10	Elec 100μF +100-20% 25 V	26415-813
C11	Elec 100μF +100-20% 25 V	26415-813
C12	Elec 100μF +100-20% 25 V	26415-813
C14	Plas 0.01μF ±10% 630 V	26555-463
C15	Cer 15pF ±0.25pF 750 V	26324-712
MR1	1N914	28336-676
R1	Met ox 3.9kΩ ±2% ½W	24573-087
R2	Met film 5.6kΩ ±2% ¼W	24773-291
R3	Met ox 15kΩ ±2% ½W	24573-101
R4	Met film 2.7kΩ ±2% ¼W	**24773-283**
R5	Met film 4.7kΩ ±2% ¼W	24773-289
R6	Met film 2.2kΩ ±2% ¼W	24773-281
R7	Met ox 1.2kΩ ±2% ½W	24573-075
R8	Met film 10kΩ ±2% ¼W	24773-297
R9	Met film 2.2kΩ ±2% ¼W	24773-281
R10	Met film 5.6kΩ ±2% ¼W	24773-291
R11	Met film 4.7kΩ ±2% ¼W	24773-289
R12	Met ox 20kΩ ±2% ½W	24573-104
R13	Met ox 470Ω ±2% ½W	24573-065
R14	Met ox 1kΩ ±2% ½W	24573-073
R15	Met ox 68kΩ ±2% ½W	24573-117
R16	Met ox 20kΩ ±2% ½W	24573-104

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
R17	Met ox 1kΩ ±2% ½W	24573-073
R18	Met ox 470Ω ±2% ½W	24573-065
R19	Met ox 20kΩ ±2% ½W	24573-104
R20	Met film 2.2kΩ ±2% ¼W	24773-281
R21	Met film 5.6kΩ ±2% ¼W	24773-291
R22	Met film 4.7kΩ ±2% ¼W	24773-289
R23	Met film 10kΩ ±2% ¼W	24773-297
R24	Carb 1MΩ ±5% ¼W	24312-966
RV1	Var WW 1.5kΩ ±10% 1W	25811-542
VT1	BCY 72	28433-487
VT2	BCY 72	28433-487
VT3	BCY 72	28433-487
VT4	2N706	28433-356
VT5	2N706	28433-356
VT6	BCY 72	28433-487

A11—AM Detector 44827-270

When ordering, prefix circuit reference with A11

C1	Cer 0.1μF +50-25% 30 V	26383-031
C2	Cer 0.1μF +50-25% 30 V	26383-031
C3	Cer 0.1μF +50-25% 30 V	26383-031
C4	Plas 680pF ±2% 125 V	26516-444
C5	Cer 0.1μF +50-25% 30 V	26383-031
C6	Plas 0.0028μF ±2% 125 V	26516-591
C7	Plas 0.0028μF ±2% 125 V	26516-591
C8	Plas 0.0028μF ±2% 125 V	26516-591
C9	Plas 0.0028μF ±2% 125 V	26516-591
L1	22μH	44290-244
L2	3.54mH	44267-403
L3	3.54mH	44267-403
MR1	CG85H	28321-201

Circuit reference	Description	M.I. code
R1	Met ox 3kΩ ±2% ½W	24573-084
R2	Met ox 910kΩ ±2% ½W	24573-072
R3	Met ox 1kΩ ±2% ½W	24573-073
R4	Met ox 100Ω ±2% ½W	24573-049
R5	Met ox 8.2kΩ ±2% ½W	24573-095
R6	Met ox 20kΩ ±2% ½W	24573-104
R7	Met ox 20kΩ ±2% ½W	24573-104
R8	Met ox 1.5kΩ ±2% ½W	24573-077
R9	Met ox 470Ω ±2% ½W	24573-065
R10	Met ox 2.4kΩ ±2% ½W	24573-082
R11	Met film 12k ±1% ¼W	24637-513
R12	Met ox 820Ω ±2% ½W	24573-071
R13	Met ox 330Ω ±2% ½W	24573-061
R14	Met ox 1MΩ ±2% ½W	24573-145
VT1	MPS 3640	28431-766
VT2	MPS 3640	28431-766
VT3	2N706	28433-356

A12—Calibrator TM 7620

When ordering, prefix circuit reference with A12

C1	Cer 33pF ±5pF 750V	26324-822
C2	Plas 0.047μF ±10% 250V	26582-206
C3	Cer 300pF ±10% 500V	26364-158
C4	Plas 0.0015μF ±2% 125V	26516-524
C5	Plas 0.047μF ±10% 250V	26582-206
C6	Cer 0.001μF ±10% 500V	26364-302
C7	Cer 100pF ±2pF 750V	26324-897
C8	Cer 0.001μF ±10% 500V	26364-302
C9	Cer 0.003μF ±25% 500V	26364-402
C10	Cer 0.004μF ±25% 500V	26364-403
C11	Elec 100μF +100-20% 25V	26417-158
C12	Cer 0.004μF ±20% 25V	26364-403
C13	Cer 0.001μF ±10% 500V	26364-302
C14	Elec 100μF +100-20% 25V	26417-158
C15	Cer 0.1μF +50-25% 30V	26383-031

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
MR1	CG85H	28321-201
MR2	CG85H	28321-201
R1	Met film 4.7kΩ ±2% ¼W	24773-289
R2	Met film 560Ω ±2% ¼W	24773-267
R3	Met film 120kΩ ±2% ¼W	24773-323
R4	Met ox 82kΩ ±2% ½W	24573-119
R5	Met film 560Ω ±2% ¼W	24773-267
R6	Met film 4.7kΩ ±2% ¼W	24773-289
R7	Met film 10kΩ ±2% ¼W	24773-297
R8	Met film 5.6kΩ ±2% ¼W	24773-291
R9	Met film 1kΩ ±2% ¼W	24773-273
R10	Met film 22kΩ ±2% ¼W	24773-305
R11	Met ox 15kΩ ±2% ½W	24573-101
R12	Met film 1kΩ ±2% ¼W	24773-273
R13	Met film 15kΩ ±2% ¼W	24773-301
R14	Met film 10kΩ ±2% ¼W	24773-297
R15	Met film 22kΩ ±2% ¼W	24773-305
R16	Met film 10kΩ ±2% ¼W	24773-297
R17	Met film 10kΩ ±2% ¼W	24773-297
R18	Met film 560Ω ±2% ¼W	24773-267
R19	Met film 470Ω ±2% ¼W	24773-265
R20	Met film 560Ω ±2% ¼W	24773-267
R21	Met film 10kΩ ±2% ¼W	24773-297
R22	Met film 15kΩ ±2% ¼W	24773-301
R23	Met film 10kΩ ±2% ¼W	24773-297
R24	Met film 10Ω ±2% ¼W	24773-225
VT1	2S323	28433-318
VT2	2S323	28433-318
VT3	2N404	44522-004
VT4	2N404	44522-004
VT5	2N404	44522-004
VT6	2N404	44522-004
VT7	2N404	44522-004
VT8	2N404	44522-004
XL1	QM27U	28311-690

A13—Power Supply Unit 44990-081

When ordering, prefix circuit reference with A13

Circuit reference	Description	M.I. code
C1	Elec 220μF +100-20% 10V	26423-251
C3	Elec 220μF +100-20% 10V	26423-251
C4	Plas 510pF ±2% 125V	26516-416
C5	Elec 100μF +100-20% 25V	26423-243
C6	Elec 100μF +100-20% 40V	26415-814
C7	Plas 680pF ±2% 125V	26516-444
C8	Plas 510pF ±2% 125V	26516-416
C9	Elec 100μF +100-20% 40V	26415-814
C10	Elec 100μF +100-20% 25V	26423-243
C12	Elec 220μF +100-20% 10V	26423-251
C13	Elec 220μF +100-20% 16V	26423-253
C14	Elec 2200μF +50-10% 40V	26426-086
C15	Elec 2200μF +50-10% 40V	26426-086
C16	Plas 0.47μF ±20% 100V	26582-523
C17	Cer Ø 4700pF +80-20% 500V	26373-665
C18	Cer Ø 4700pF +80-20% 500V	26373-665
C19	Cer Ø 4700pF +80-20% 500V	26373-665
C20	Cer Ø 4700pF +80-20% 500V	26373-665
C21	Cer Ø 4700pF +80-20% 500V	26373-665
D1 to D8	1N4004	28357-028
FS1	Fuse link 100mA	23411-052
	Fuse holder	23416-191
	Fuse holder cover	37575-121

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
IC1	μA 723	28461-706
IC3	μA 723	28461-706
IC4	μA 723	28461-706
PL1	Supply plug	23423-159
R2	Met film 12kΩ ±2% ¼W	24773-299
R3	Var WW 2.2kΩ ±10% 1W	25811-021
R4	Met film 3.9kΩ ±2% ¼W	24773-287
R5	Met film 6.2kΩ ±2% ¼W	24773-292
R6	Met film 330Ω ±2% ¼W	24773-261
R7	Met ox 1.8Ω ±10% ½W	24582-559
R8	Met film 6.8kΩ ±2% ¼W	24773-293
R9	Met film 6.8kΩ ±2% ¼W	24773-293
R10	Met film 12kΩ ±2% ¼W	24773-299
R11	Var WW 2.2kΩ ±10% 1W	25811-021
R12	Met film 4.7kΩ ±2% ¼W	24773-289
R14	Met film 560Ω ±2% ¼W	24773-267
R16	Met film 12kΩ ±2% ¼W	24773-299
R17	Var WW 2.2kΩ ±10% 1W	25811-021
R18	Met film 4.7kΩ ±2% ¼W	24773-289
R19	Met film 6.2kΩ ±2% ¼W	24773-292
R20	Met film 330Ω ±2% ¼W	24773-261
R21	Met film 10Ω ±2% ¼W	24773-225
R22	Met film 12kΩ ±2% ¼W	24773-299
R23	Met film 12kΩ ±2% ¼W	24773-299
SA	Mains voltage selector	23467-155
T1	Mains transformer	43490-014
TR1	BCY72	28433-487
TR2	2N3055	28456-567
TR3	2N3055	28456-567
TR4	2N3055	28456-567
	Interference suppression filter	23642-901

Circuit reference	Description	M.I. code
A14—Component Board TM 8742		
When ordering, prefix circuit reference with A14		
C1	Elec 100μF +100-20% 25V	26417-158
R1	Met ox 18kΩ ±2% ½W	24573-103
RV1	Var WW 5kΩ ±10% 1W	25811-547
A15—Oscillator Switch 44990-084		
When ordering, prefix circuit reference with A15		
PLE	Plug, 50Ω, BNC	23443-307
PLJ	Plug, 50Ω, BNC	23443-307
R1	Met film 510Ω ±2% ¼W	24773-266
SA	OSCILLATOR switch	44340-061
SKF	Socket, 50Ω, BNC	23443-540
SKG	Socket, 2mm	23421-126
SKH	Socket, 50Ω, GP	23444-146
Crystal Oscillator TK 2302		
C1	Cer 0.001μF +80-20% 500 V	26383-242
C2	Cer 0.01μF +80-20% 100 V	26383-055
C3	Cer 0.01μF +80-20% 100 V	26383-055
C4	Tant 4.7μF ±20% 35 V	26486-556
C5	Plas 150pF ±2% 125 V	26516-287
C6	Cer 0.01μF +80-20% 100 V	26383-055
C7	Cer 0.01μF +80-20% 100 V	26383-055
C8	Cer 0.01μF +80-20% 100 V	26383-055
C9	Cer 0.01μF +80-20% 100 V	26383-055
C10	Cer 0.01μF +80-20% 100 V	26383-055
C11	Cer 0.01μF +80-20% 100 V	26383-055
C12	Cer 0.01μF +80-20% 100 V	26383-055
C13	Cer 0.01μF +80-20% 100 V	26383-055
C14	Cer 0.001μF +80-20% 500 V	26383-242

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
D1	BB105	28381-096
D2	BB105	28381-096
D3	BB105	28381-096
D4	BB105	28381-096
L1	Oscillator coil	44290-152
L2	Harmonic generator coil	44251-207
L3	Harmonic generator coil	35124-411
L4	Harmonic generator coil	44251-207
L5	Harmonic generator coil	35124-411
PLA	Plug, 2mm	23421-056
PLB	Plug, 50Ω, GP	23444-027
R1	Var carb 20kΩ ±20% ½W	25621-301
R2	Var carb 20kΩ ±20% ½W	25621-301
R3	Var carb 20kΩ ±20% ½W	25621-301
R4	Met film 1.2kΩ ±2% ¼W	24773-275
R5	Met film 1.2kΩ ±2% ¼W	24773-295
R6	Met film 1.5kΩ ±2% ¼W	24773-277
R7	Met film 47Ω ±2% ¼W	24773-241
R8 †	Met film 1kΩ ±2% ¼W	24773-273
R9	Met film 270Ω ±2% ¼W	24773-259
R10	Met film 22kΩ ±2% ¼W	24773-305
R11	Met film 100Ω ±2% ¼W	24773-249
R12	Met film 220Ω ±2% ¼W	24773-257
R13	Met film 47Ω ±2% ¼W	24773-241
R14	Met film 100Ω ±2% ¼W	24773-249
R15	Met film 220Ω ±2% ¼W	24773-257
R16	Met film 47Ω ±2% ¼W	24773-241
R17	Met film 1kΩ ±2% ¼W	24773-273
R18	Met film 1kΩ ±2% ¼W	24773-273
R19	Met film 1kΩ ±2% ¼W	24773-273
SA	CRYSTAL switch	44340-062
TR1	BFY90	28452-157
TR2	BSX20	28452-197
TR3	BSX20	28452-197

Mechanical parts

Knob, FREQUENCY RANGE switch	41145-407
Knob, Coarse TUNE FREQUENCY control	41149-021
Knob, Fine TUNE FREQUENCY control	41149-017
Knob, RF LEVEL control	41149-018
Knob, DE-EMPHASIS switch	41146-011
Knob, OSCILLATOR switch	41146-011
Knob, SET AM control	41149-017
Knob, FUNCTION switch	41146-014
Knob, MODULATION RANGE switch	41146-011
Knob, FREQUENCY RESPONSE switch	41146-011
Window, TUNING dial	37490-107
Lower cover (feet and stand not included)	35417-538
Attachment screw (four)	21838-457
Washer (four)	21177-650
Stand	35116-109
Front foot (two)	37588-111
Attachment screw	21851-463
Rear foot (two)	22315-663
Attachment screw	21851-463
Nut	21882-110
Washer	21177-650
Top cover	35523-419
Attachment screw (four)	21838-457
Washer (four)	21177-650
Locking plate, Mains voltage selector	34444-116
Attachment screw (two)	21837-357
Washer (two)	21177-648

For symbols and abbreviations see introduction to this chapter

Chapter 7

Circuit diagrams

Circuit notes

1. ARRANGEMENT

The inter-unit wiring diagram, Fig. 7.1, shows all sub-assembly units in the equipment together with their reference designators (A1, A2 etc.) and part numbers. Components that are not on a sub-assembly are part of the main chassis assembly (designated A0).

Circuit diagrams are arranged in order of the sub-assembly designations.

2. COMPONENT VALUES

Resistors : No suffix = ohms, k = kilohms, M = megohms.
Capacitors : No suffix = microfarads, p = picofarads.
Inductors : No suffix = henries, m = millihenries, μ = microhenries.
† : value selected during test, nominal value shown.

3. VOLTAGES

Printed in italics. Voltages are d.c. and relative to chassis unless otherwise indicated. Measured with a 20 kΩ/V meter.

4. SYMBOLS

arrow indicates clockwise rotation of knob.

preset component.

panel marking.

indicates points at same supply potential.

waveform reference number.

5. SWITCHES

Rotary switches are drawn schematically. Letters indicate the control knob setting as shown in the key diagrams. The sequence of sections reading from control knob end is as follows :-

1F = 1st section, front
1B = 1st section, back
2F = 2nd section, front
etc.

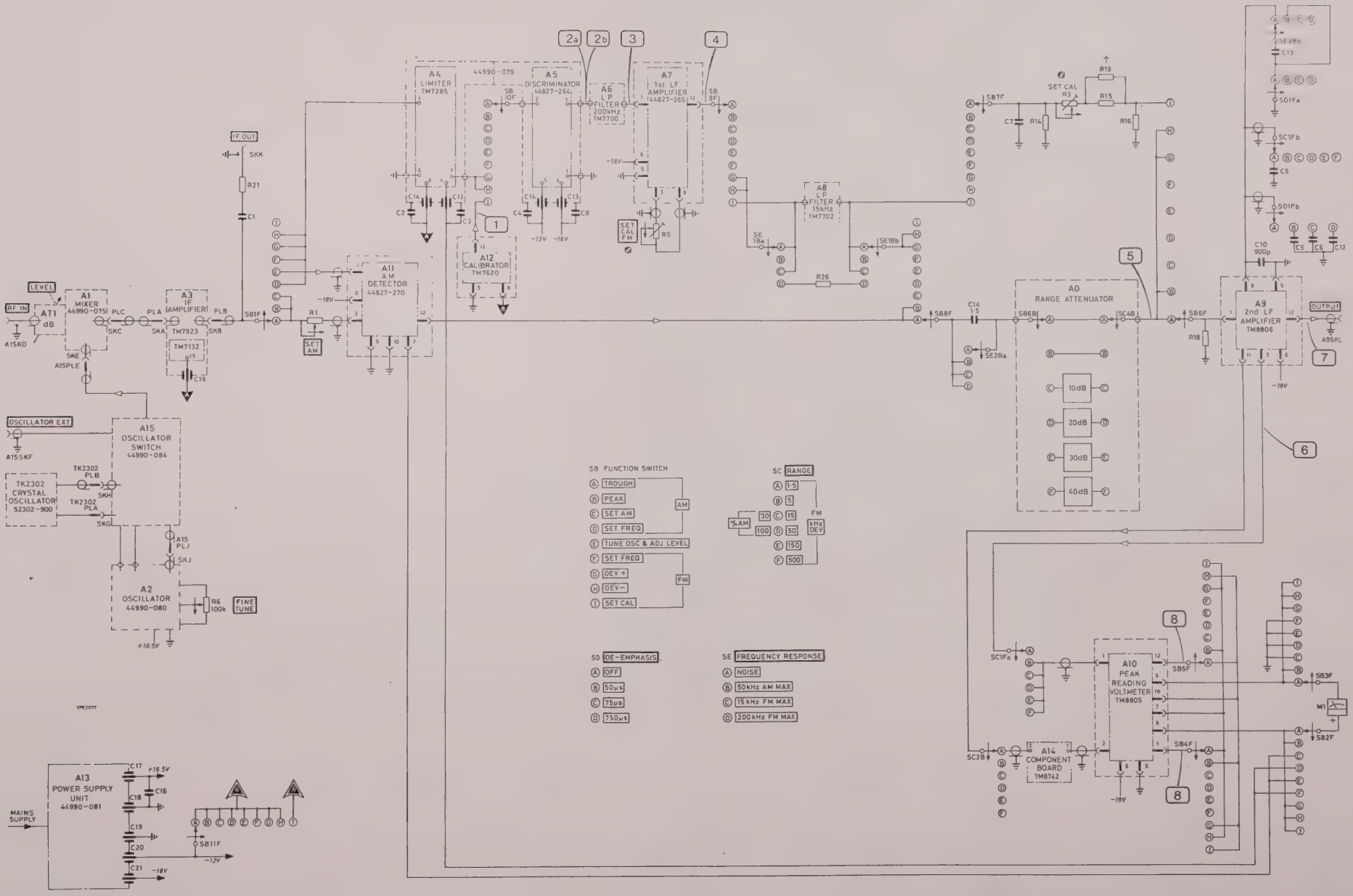


Fig. 7.1 Inter-unit wiring

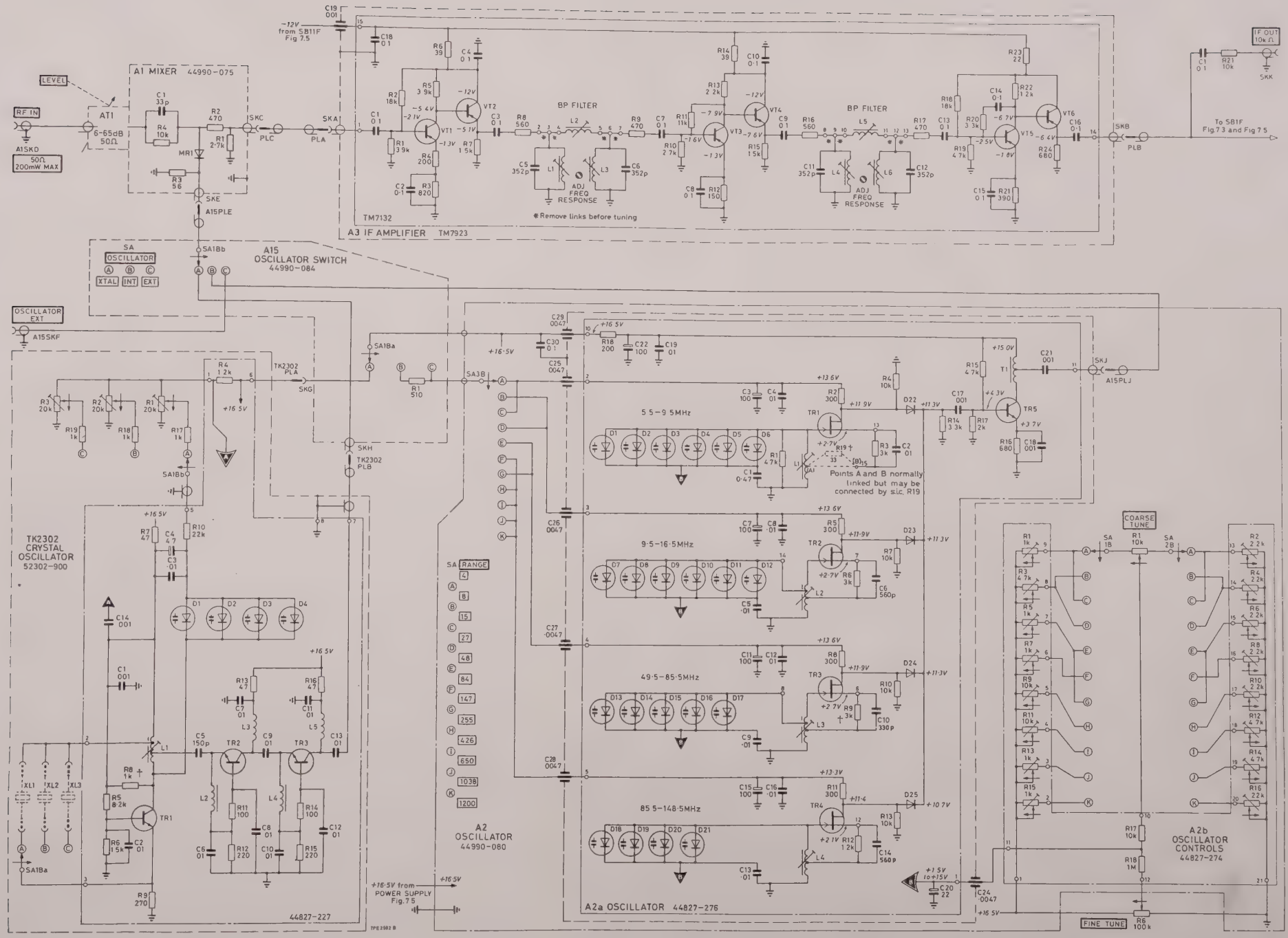


Fig. 7.2 Mixer, oscillators and i.f. amplifier

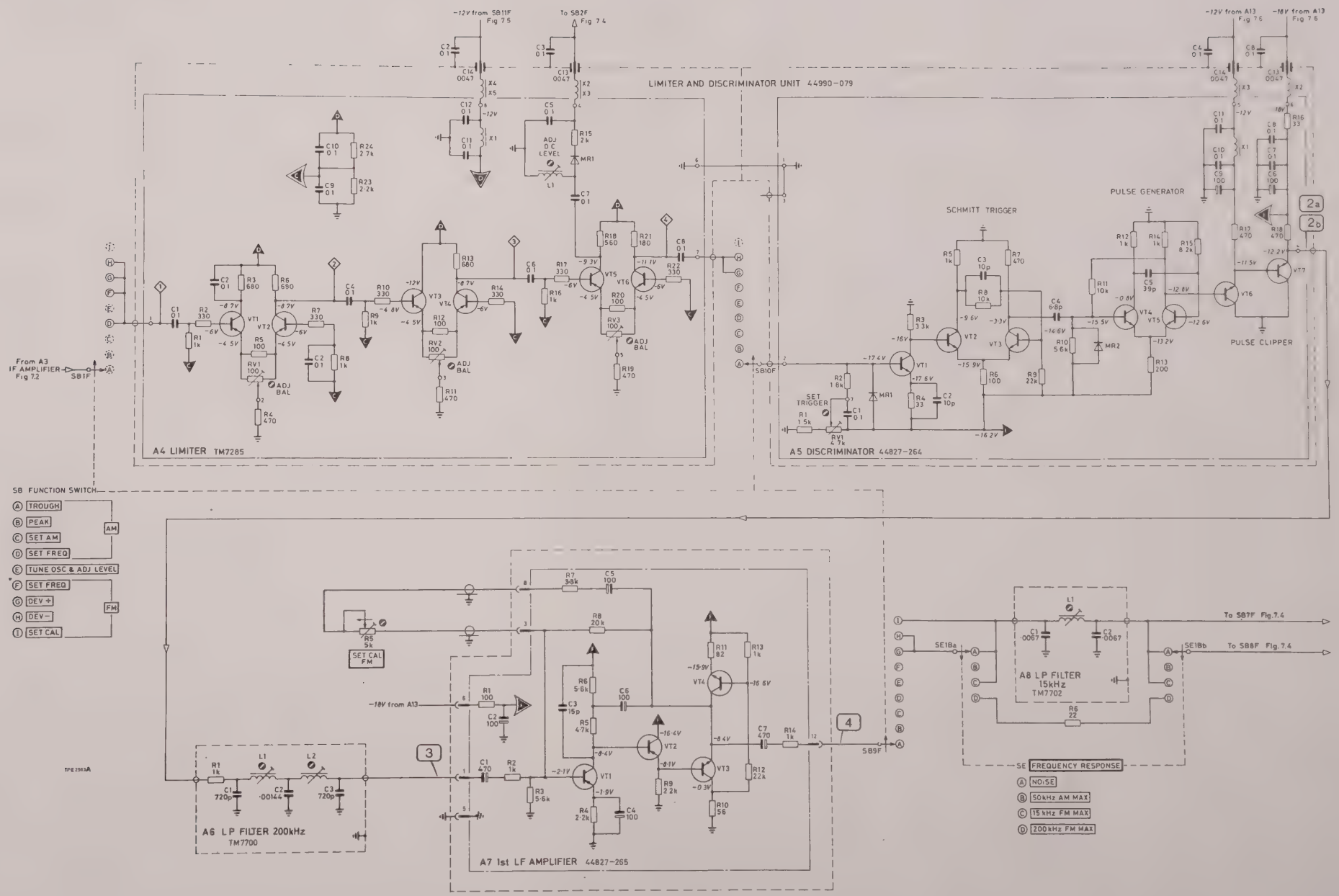


Fig. 7.3 Limiter, discriminator and 1st l.f. amplifier

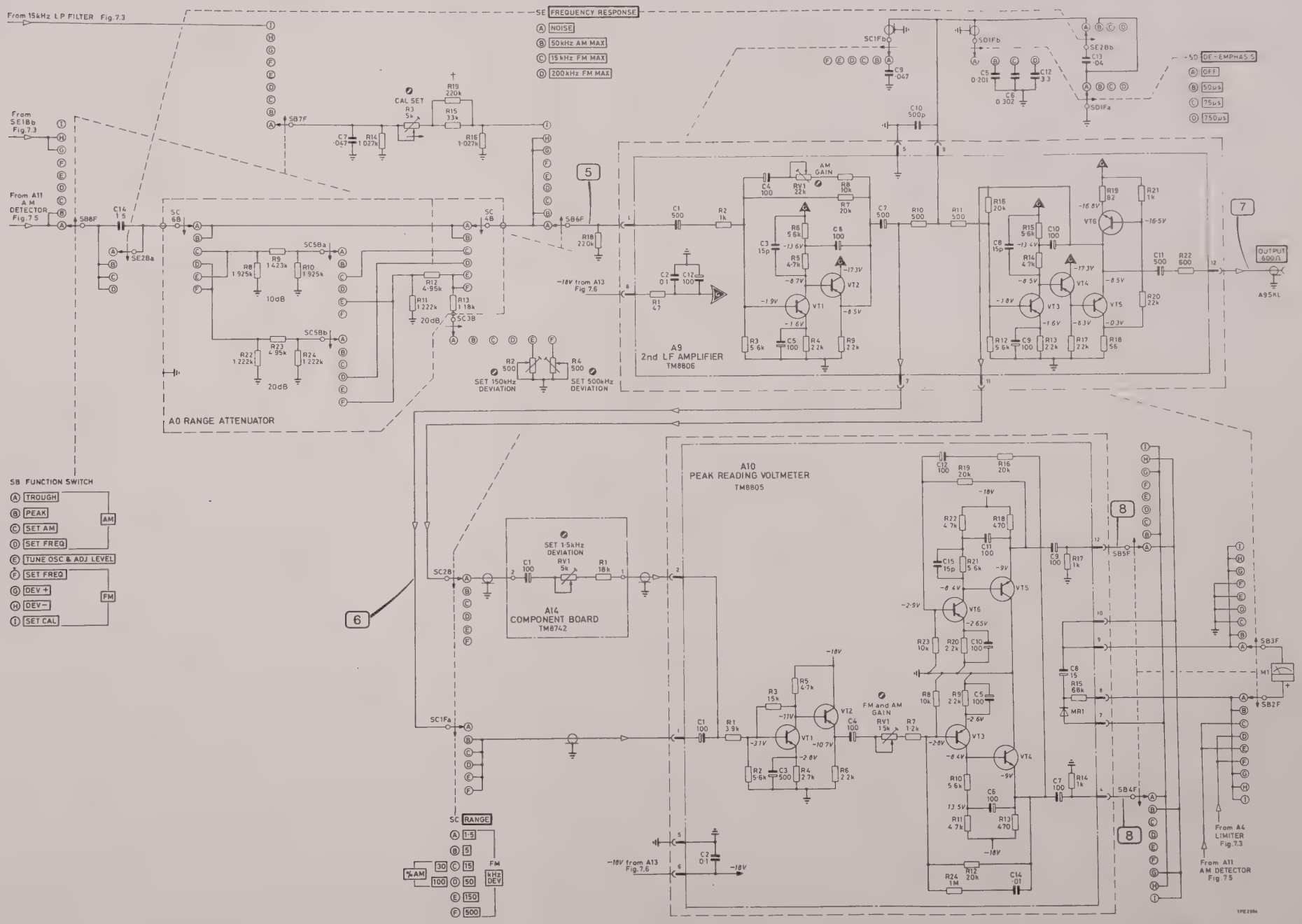


Fig. 7.4 2nd l.f. amplifier and peak reading voltmeter

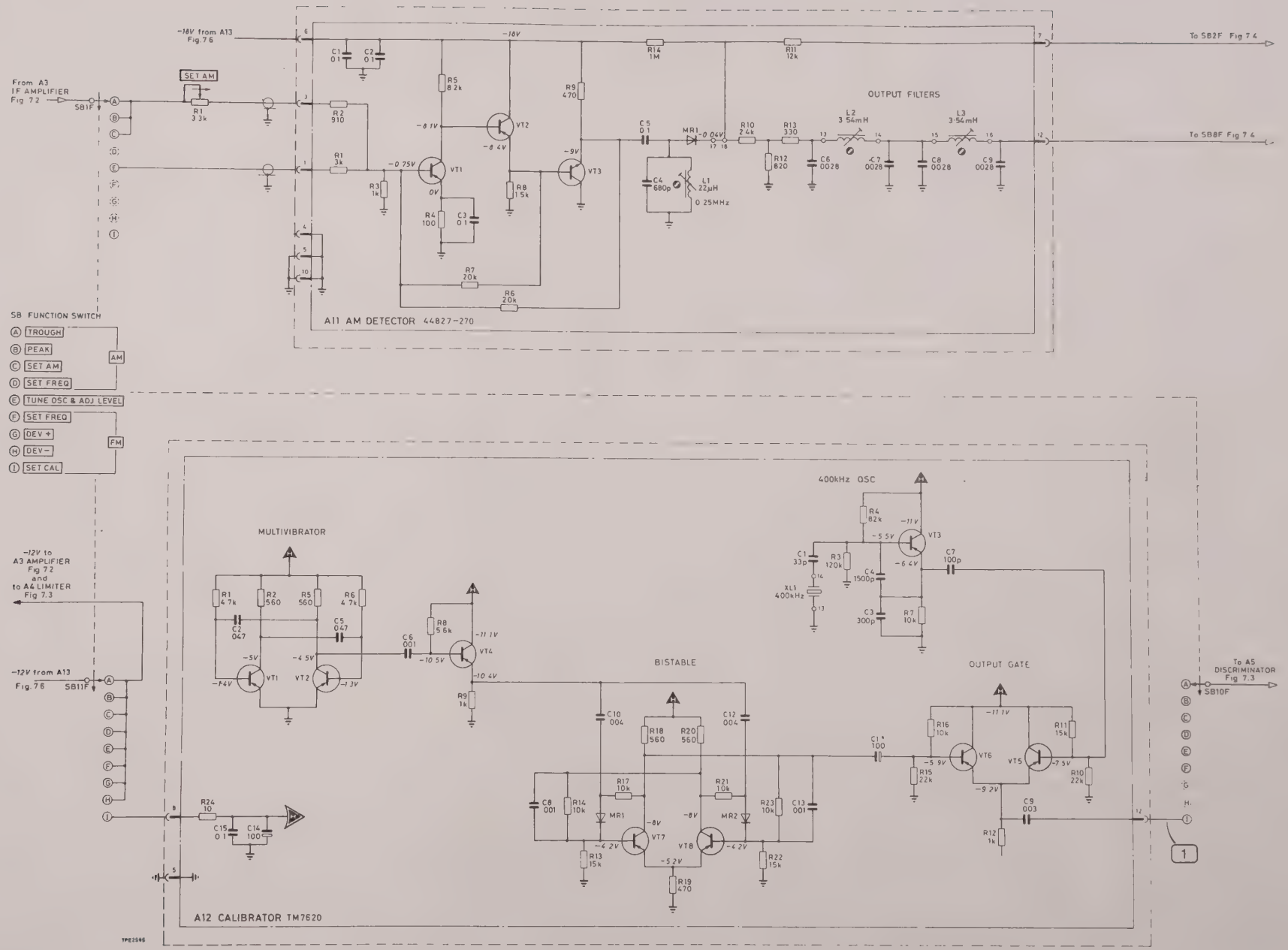


Fig. 7.5 AM detector and calibrator

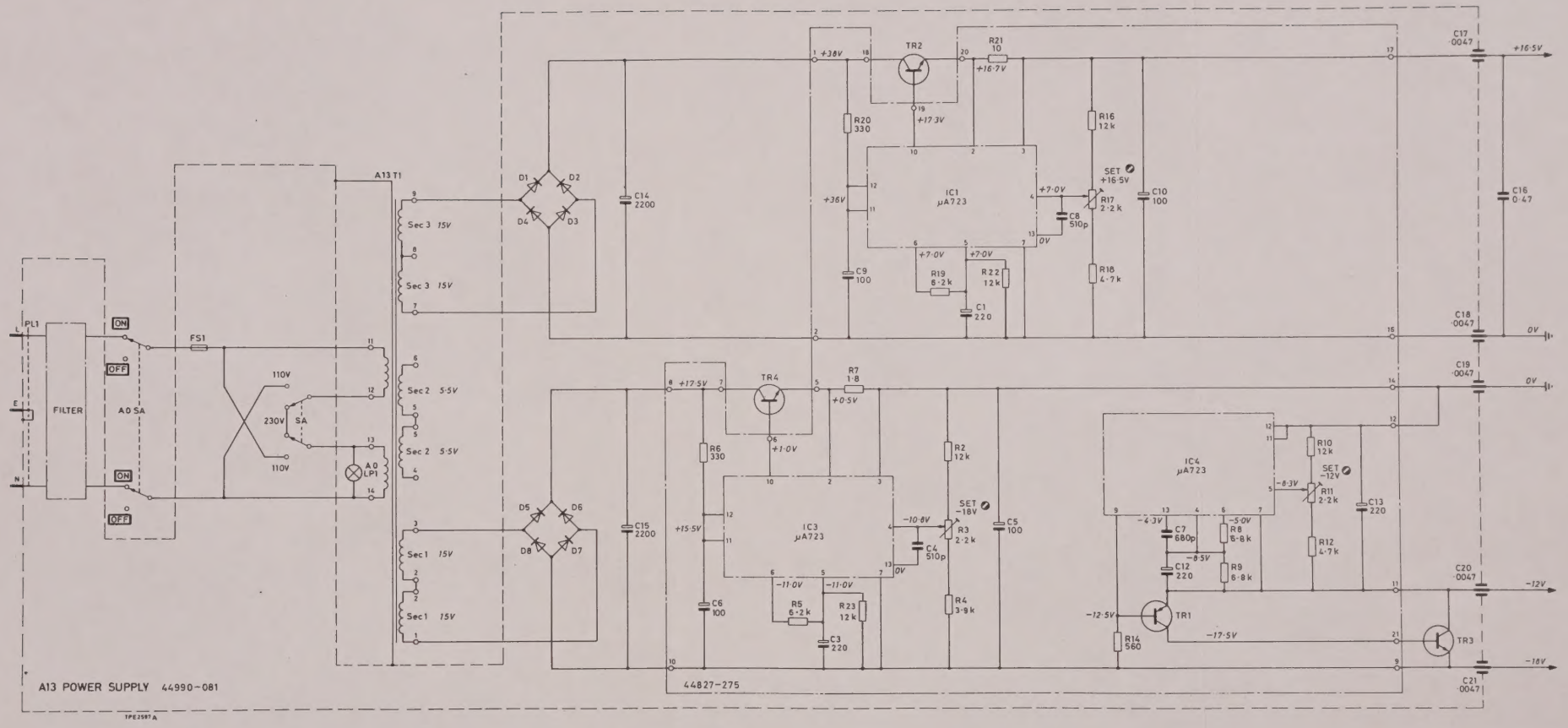


Fig. 7.6 Power supply unit

Oxford
ESSELTE
10%

MP MASTER